PHYSICO-THEOLOGY:

OR,

A DEMONSTRATION

OF THE

BEING AND ATTRIBUTES OF GOD,

FROM

HIS WORKS OF CREATION.

BEING THE

Subſtance of Sixteen Diſcourſes delivered in St. Mary-le-Bow Church, London, at the Hon. Mr. Boyle's Lectures, in the Years 1711 and 1712.

By the Rev. W. DERHAM,

CANON OF WINDSOR, RECTOR OF UPMINSTER IN ESSEX, AND F. R. S.

A NEW EDITION;
With additional Notes; a Tranſlation of the Latin and Greek Quotations; and a Life of the Author.

IN TWO VOLUMES.

ILLUSTRATED WITH PLATES.

Mala & impia conſuetudo eſt contra Deos diſputare, ſive animo id ſit, ſive ſimulatè. —"It is a wicked and impious cuſtom to diſpute againſt the exiſtence and attributes of God, whether it be done in earneſt, or only through affectation." Cic. *de Nat. Deor.* l. 2. *fine.*

VOL. I.

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1798.

TO THE

MOST REVEREND FATHER IN GOD,

THOMAS

LORD ARCHBISHOP OF CANTERBURY*,

PRIMATE OF ALL ENGLAND, &c.

THE SURVIVING TRUSTEE OF THE HONOURABLE *MR. BOYLE'S LECTURES.*

May it pleaſe your GRACE,

I May juſtly put theſe LECTURES under your Grace's patronage, their publication being wholly owing to you: for having the honour to be a Member of the ROYAL SOCIETY, as well as a *Divine*, I was minded to try what I could do towards the improvement of *philoſophical* matters to *theological* uſes; and accordingly laid a ſcheme of what I have here publiſhed a part of, and when I had little elſe to do, I drew up what I had to

* Dr. Thomas Teniſon.

ſay, making it rather the diverting exerciſes of my *leiſure hours*, than more ſerious *theological ſtudies*. This work (although I made a conſiderable progreſs in it at firſt, whilſt a novelty, yet) having no thoughts of publiſhing, I laid aſide, until your Grace, being informed of my deſign by ſome of my learned friends, both of the Clergy and Laity, was pleaſed to call me to the unexpected honour of preaching Mr. *Boyle*'s LECTURES: an honour I was little aware of in my country privacy, and not much acquainted with perſons in high ſtations, and not at all particularly with your Grace. So that therefore as it pleaſed your Grace, not only to confer an unſought, profitable honour upon me (a ſtranger), but alſo to continue it for two years, out of your good opinion of my performance, in ſome meaſure anſwering Mr. *Boyle*'s end; ſo I can do no leſs than make this public, grateful acknowledgment of your Grace's great and unexpected favour.

But it is not myſelf alone; but the whole LECTURE alſo is beholden to your Grace's

kind and pious endeavours. It was you that encouraged this noble charity, and aſſiſted in the ſettlement of it, in the honourable *Founder*'s lifetime; and ſince his death, it was you that procured a more certain ſalary for the LECTURERS, paid more conſtantly and duly than it was before *.

Theſe

* It may not only gratify the Reader's curioſity, but alſo be of uſe for preventing encroachments in time to come, to give the following account of Mr. *Boyle*'s Lectures.

Mr. *Boyle*, by a codicil, dated *July* the 28th, 1691, and annexed to his will, charged his meſſuage or dwelling-houſe, in *St. Michael's, Crooked Lane, London*, with the payment of the clear yearly rents and profits thereof, to ſome learned Divine in *London*, or within the bills of mortality, to be elected for a term not exceeding three years, by his Grace the preſent Lord Archbiſhop of *Canterbury*, (then Dr. *Teniſon*,) Sir *Henry Aſhhurſt*, Sir *John Rotheram*, and *John Evelyn*, Eſq. The buſineſs he appointed thoſe Lectures for, was, among others, *To be ready to ſatisfy real ſcruples, and to anſwer ſuch new objections and difficulties as might be ſtarted, to which good anſwers had not been made.* And alſo, *To preach eight ſermons in the year, the firſt* Monday *of* January, February, March, April, *and* May; *and of* September, October, *and* November. The ſubject of theſe ſermons was to be, *The proof of the Chriſtian religion againſt notorious infidels*, viz. *Atheiſts, Theiſts, Pagans, Jews,*

Theſe benefits, as I myſelf have been a ſharer of, ſo I ſhould be very ungrateful, ſhould I not duly acknowledge, and repay with my repeated thanks and good wiſhes. And that the Infinite Rewarder of well-doing may give your *Grace* a plentiful reward of theſe, and your many other, both public and private, benefactions, is the hearty wiſh of

YOUR GRACE'S

Moſt humble and thankful

Son and Servant,

W. DERHAM.

Jews, and Mahometans; not deſcending lower to any controverſies that are among Chriſtians themſelves. But by reaſon the Lecturers were ſeldom continued above a year, and that the houſe ſometimes ſtood empty, and tenants brake, or failed in due payment of their rent, therefore the ſalary ſometimes remained long unpaid, or could not be gotten without ſome difficulty: to remedy which inconvenience, his preſent Grace of *Canterbury* procured a yearly ſtipend of 50 *l.* to be paid quarterly for ever, charged upon a farm in the pariſh of *Brill* in the county of *Bucks*: which ſtipend is accordingly very duly paid, when demanded, without fee or reward.

THE

AUTHOR's PREFACE.

TO THE READER.

AS the noble *Founder* of the LECTURES I have had the honour of preaching, was a great improver of *natural knowledge*, ſo, in all probability, he did it out of a pious end, as well as in purſuit of his *genius*. For it was his ſettled opinion, that nothing tended more to cultivate true religion and piety in a man's mind, than a thorough ſkill in philoſophy. And ſuch effect it manifeſtly had in him, as is evident from divers of his publiſhed pieces; from his conſtant deportment in *never mentioning the name of* GOD *without a pauſe, and viſible ſtop in his diſcourſe* *; and from the noble foundation of his Lectures for the honour of GOD, and the generous ſtipend he allowed for the ſame.

* Vide *Biſhop* Burnet's *Funeral Sermon*, p. 24.

And

And forasmuch as his Lectures were appointed by him for the *proof of the Christian religion against atheists and other notorious infidels* *, I thought, when I had the honour to be made his Lecturer, that I could not better come up to his intent, than to attempt a demonstration of the *Being* and *Attributes of* GOD, in what I may call Mr. *Boyle*'s own, that is a *Physico-theological*, way. And, besides that it was for this very service that I was called to this honour, I was the more induced to follow this method, by reason none of my learned and ingenious predecessors in these Lectures have done it on purpose, but only casually, in a transient, piece-meal manner; they having made it their business to prove the great points of Christianity in another way, which they have accordingly admirably done. But considering what our *honourable Founder*'s opinion was of *natural knowledge*, and that his intent was, that those matters, by passing through divers hands, and by being treated of in different methods, should take in most of what could be said upon the subject; I hope my performance may be acceptable, although one of the meanest.

As for others, who have before me done something of this kind; as *Mersenne* on *Genesis*; Dr.

* Vide Mr. *Boyle*'s Will.

Cockburne

Cockburne in his Eſſays; Mr. *Ray* in his *Wiſdom of God*, &c. and I may add the firſt of Mr. *Boyle*'s *Lecturers*, the moſt learned Dr. *Bentley*, in his *Boyle*'s *Lectures*, the eloquent Archbiſhop of *Cambray* (and I hear, the ingenious Monſieur *Perault* hath ſomething of this kind, but never ſaw it): I ſay, as to theſe learned and ingenious authors, as the Creation is an ample ſubject, ſo I induſtriouſly endeavoured to avoid doing over what they before had done; and for that reaſon did not, for many years, read their books until I had finiſhed my own. But when I came to compare what each of us had done, I found myſelf in many things to have been anticipated by ſome or other of them, eſpecially by my friend the late great Mr. *Ray*. And therefore in ſome places I ſhortened my diſcourſe, and referred to them; and in a few others, where the thread of my diſcourſe would have been interrupted, I have made uſe of their authority, as the beſt judges; as of Mr. *Ray*'s, for inſtance, with relation to the mountains and their plants, and other products. If then the Reader ſhould meet with any thing mentioned before by others, and not accordingly acknowledged by me, I hope he will candidly think me no plagiary, becauſe I can aſſure him I have all along (where I was aware of it) cited my authors with their due praiſe. And it is ſcarcely poſſible, when men write on the ſame, or a

ſubject near a-kin, and the obſervations are obvious, but that they muſt often hit upon the ſame thing. And frequently this may happen from perſons making obſervations about one and the ſame thing, without knowing what each other hath done; which indeed, when the firſt edition of my book was nearly printed off, I found to be my own caſe, having (for want of Dr. *Hook*'s *Micrography* being at hand, it being a very ſcarce book, and many years ſince I read it) given deſcriptions of two or three things which I thought had not been tolerably well obſerved before, but are deſcribed well by that curious gentleman.

One is a *feather*, the mechaniſm of which we in the main agree in, except in his repreſentation in *fig.* 1. *ſcheme* 22. which is ſomewhat different from what I have repreſented in my *fig.* 9, 10, 11. Plate H. But I can ſtand by the truth, though not the elegance of my figures *. But as to the other differences, they are accidental, occaſioned by our taking the parts in a different view, or in a different part of a vane; and to ſay the truth, (not flattering myſelf, or detracting from the admirable obſervations of that great man,) I have hit

* The former Editions of this work contained only a ſingle Plate, and that very poorly executed.

upon

upon a few things that escaped him, being enabled to do so, not only by the help of such microscopes as he made use of, but also by those made by Mr. *Wilson*, which exceed all I ever saw, whether of *English*, *Dutch*, or *Italian make*; several of which sorts I have seen and examined.

The other thing we have both of us figured and described is, *the sting of a bee or wasp*; in which we differ more than in the last. But by a careful re-examination, I find, that although Dr. *Hook*'s observations are more critical than any where before, yet they are not so true as mine. For as to the *scabbard*, (as he calls it,) I could never discover any beards thereon; and I dare be confident there are none, but what are on the two spears. And as to the point of the *scabbard*, he hath represented it as tubular or bluntish at the top; but it really terminates in a sharp point, and the two spears and the poison come out at a slit, or longish hole, a little below the top or point. And as to the spears, he makes them to be but one, and that the point thereof lies always out of the scabbard. But, by a strict examination, they will be found to be two, as I have said, and that they always lie within the *scabbard*, except in stinging; as I have represented them, in Plate E,

fig. 2.

fig. 2. from the tranſparent ſting of a waſp. And as to the ſpear being made of joints, and parted into two, as his *fig.* 2. *ſcheme* 16. repreſents, I could never upon a review diſcover it to be ſo, but imagine, that by ſeeing the beards lying upon or behind the ſpears, he might take them for joints, and by ſeeing the point of one ſpear lie before the other, he might think the ſpear was parted in two. But leſt the Reader ſhould think himſelf impoſed upon both by Dr. *Hook* and *myſelf*, it is neceſſary to be obſerved, that the *beards* (or *tenter-hooks*, as Dr. *Hook* calls them) lie only on one ſide of each ſpear, not all round them; and are therefore not to be ſeen, unleſs they are laid in a due poſture in the microſcope, *viz.* ſide-ways, not under, or a-top the ſpear.

The laſt thing (which ſcarce deſerves mention) is the mechaniſm of the *hair*, which Dr. *Hook* found to be ſolid, like a long piece of horn, not hollow, as *Malpighi* found it in ſome animals. And I have found both thoſe great men to be in ſome meaſure in the right, the hair of ſome animals, or in ſome parts of the body, being very little, if at all, tubular; and in others, particularly *mice*, *rats*, and *cats*, to be as I have repreſented in Plate F. fig. 2, 3, 4, 5.

And

And now if my inadvertency in other things hath no worſe effect than it hath had in theſe, namely, to confirm, correct, or clear others obſervations, I hope the Reader will excuſe it, if he meets with any more of the like kind. But not being conſcious of any ſuch thing, (although probably there may be many ſuch,) I am more ſolicitous to beg the reader's candour and favour, with relation both to the *text* and *notes*: in the former of which, I fear, he will think I have as much under-done, as in the latter over-done, the matter: but for my excuſe, I deſire it may be conſidered, that the textual part being ſermons, to be delivered in the pulpit, it was neceſſary to inſiſt but briefly upon many of the works of God, and to leave out many things that might have been admitted in a more free diſcourſe. So that I wiſh it may not be thought I have ſaid too much rather than too little for ſuch an occaſion and place. And indeed, I had no ſmall trouble in expunging ſome things, altering many, and ſoftening the moſt, and, in a word, giving in ſome meaſure the whole a different dreſs than what I had at firſt drawn it up in, and what it now appears in.

And as for the *notes*, which may be thought too large, I confeſs I might have ſhortened them, and

and had thoughts of doing it, by casting some of them into the text, as an ingenious, learned friend advised. But when I began to do this, I found it was in a manner to new-make all, and that I should be necessitated to transcribe the greatest part of the book, which (having no assistant) would have been too tedious for me, being pretty well fatigued with it before. I then thought it best to pare off from some, and to leave out others, and accordingly did so in many places, and would have done it in more, particularly in many of the *citations* out of the *Ancients*, both poets and others, as also in many of the *anatomical observations*, and many of my own and others observations; but then I considered, as to the first, that those citations do (many of them at least) shew the sense of mankind about GOD's works, and that the most of them may be acceptable to young gentlemen at the universities, for whose service these Lectures are greatly intended. And as to the anatomical notes, and some others of the like nature, most of them serve either to the confirmation, or the illustration, or explication of the text, if not to the learned, yet to the unskilful, less learned reader; for whose sake, if I had added more, I believe he would forgive me. And lastly, as to the observations of myself, and some others, where

where it happens that they are long, it is commonly where a neceſſity lay upon me of fully expreſſing the Author's ſenſe, or my own, or where the thing was new, and never before publiſhed; in which caſe, it was neceſſary to be more expreſs and particular, than in matters better known, or where the Author may be referred unto.

In the former editions I promiſed *another part I had relating to the Heavens*, if I was thereunto encouraged. And two large impreſſions of this book, having been ſold off, ſo as to admit of a third before the year was gone about; and hearing that it is tranſlated into two, if not three languages; but, eſpecially, being importuned by divers learned perſons, both known and unknown, I have thought myſelf ſufficiently engaged to perform that promiſe; and have accordingly publiſhed that part.

So that I have now carried my *ſurvey* through moſt parts of the viſible creation, except the *waters*, which are for the moſt part omitted; and the *vegetables*, which, for the want of time, I was forced to treat of in a perfunctory manner. And to the undertaking of the former of theſe, having

received

received divers ſolicitations from perſons unknown, as well as known, I think myſelf bound in civility to own their favour, and to return them my hearty thanks for the kind opinion they have ſhewn of my other performances, that they have encouraged me to undertake this other taſk. And accordingly I have begun it, and (as far as my affairs will permit) have made ſome progreſs in it: but age and avocations growing upon me, I begin to fear I ſhall ſcarce be able to finiſh it as I would, and therefore muſt recommend that ample and noble ſubject to others, who have more leiſure, and would do it better than I.

As to *additions*, I have been much ſolicited thereto by divers curious and learned perſons, who would have had me to inſert ſome of their obſervations, and many more of my own: but in a work of this nature, this would have been endleſs; and although the book would thereby be rendered much better and more complete, yet I could by no means excuſe ſo great an injuſtice to the purchaſers of the former editions. And therefore (except in the ſecond edition, where it was not eaſy to be avoided) few additions or alterations have been made, beſides what were typographical, or of ſmall conſideration. Only in the third edition

tion I amended the firſt paragraph of *note* 1. *chap.* 5. *book* i. concerning *Gravity*; and in the fourth, *page* 16 and 18, I inſerted two paſſages out of *Seneca*, that were inadvertently left out, and corrected many things, that upon a careful review ſeemed to want amendment.

And laſtly, as to the *Analyſis*, it was added at the requeſt of ſome of my learned and ingenious friends; and although it might have been contracted, they would not ſuffer it to be ſo.

ACCOUNT

ACCOUNT

OF THE

LIFE AND WRITINGS

OF

THE REV. DR. WILLIAM DERHAM.

WILLIAM DERHAM was born at Stowton in the county of, Worcefter, 26th November 1657. Of the condition of his parents we have no account; though it is probable their rank in life was refpectable, as their fon enjoyed the benefit of a moft liberal education. The rudiments of his literary knowledge he received at Blockley in Worcefterfhire, under the Reverend Mr. Nathaniel Collier; and in May 1675, being then in the 18th year of his age, he became a ftudent of Trinity College, Oxford, and had for his tutor the learned Dr. Willes, father to that eminent Lawyer, who was afterwards Lord Chief Juftice of the Common Pleas. Mr. Derham took the degree of Bachelor of Arts, January 28, 1678-9; and being diftinguifhed no lefs by his learning and in-

genuity, than by his many amiable qualities of mind, he ſo ingratiated himſelf with the Preſident of his college, Dr. Bathurſt, as to obtain from him a moſt warm recommendation to Dr. Ward, Biſhop of Saliſbury; by whoſe intereſt, as ſoon as he had entered into holy orders, he procured the appointment of domeſtic chaplain to the Dowager Lady Grey of Warke. He was ordained Deacon, May 29th, 1681, by Dr. Compton, Biſhop of London; and Prieſt in the year following, by the Biſhop of Saliſbury.

On the 5th July 1682, he was preſented by Mr. Neville to the vicarage of Wargrave in Berkſhire; and in 1689 he obtained the rectory of Upminſter in Eſſex, a living of above 200 l. a year, and at the ſhort diſtance of 15 miles from the metropolis; a ſituation, to a perſon of our Author's turn of mind, highly deſirable, as giving him the enjoyment of the ſociety of thoſe men of letters who cultivated ſimilar purſuits, the opportunity of attending the meetings of the Royal Society, and the eaſy attainment of ſuch books and inſtruments as were neceſſary for the proſecution of his favourite ſciences of natural hiſtory and experimental philoſophy. To theſe ſtudies he therefore applied himſelf with an enthuſiaſm

enthusiasm congenial to his nature, and with a measure of success proportioned to his exertions.

Mr. Derham's reputation as a philosopher had very early procured him the honour of being elected a Fellow of the Royal Society; and he soon approved himself one of its most useful and industrious members, by furnishing a very great number of ingenious essays and observations, which, during a period of above thirty years, form a valuable part of the Philosophical Transactions.

Of these the most worthy of notice are: 1. *Description and Uses of an Instrument for finding the Meridian of any Place;* and for observing the Transits of the Celestial Bodies over it. The principal uses of this instrument, which is extremely simple in its construction, the Author observes, are, 1*mo*, That we may see when it is *noon*, in all places within one, two, or at most three seconds of time; so that it much exceeds in accuracy all sorts of sun-dials; and that, without the necessity of any adjustment to particular latitudes, &c. 2*do*, It points out with exactness the precise errors of all sun-dials. 3*tio*, As the fixed stars as well as the sun may be seen to transit the meridian, the hour of the night

as

as well as of the day may thereby be known with great preciſion. 4*to*, The hour of the day and night being thus diſcoverable to within one, two, or three ſeconds, the inſtrument may be uſeful in finding the exact difference of meridians, either by the eclipſes of Jupiter's ſatellites, or the occultation of the fixed ſtars by the moon. 5*to*, A meridian line may thereby be continued for many miles. The account of this uſeful inſtrument is to be found in No. 291 of the Philoſophical Tranſactions.

2. *Magnetical Experiments and Obſervations.*— This paper is publiſhed in the Philoſophical Tranſactions, No. 303. The chief experiments here noticed are, the bending a magnetiſed wire into an annular form, ſo as to make the two ends meet, and then bringing it back to a ſtraight figure; when it was found to have totally loſt its verticity, ſo as to be quite indifferent to the poles of the loadſtone; either end of it becoming capable of being attracted by either pole of the magnet, in the ſame manner as if the wire had never been touched at all, or its magnetic virtue had been deſtroyed by heating it red hot. The cauſe of this extraordinary phænomenon the Author ſuppoſes to be the ſeparation of the

the fibres of the iron by the extreme violence it has ſuffered, and the change of their ſituation with reſpect to each other. In this paper Mr. Derham details many curious experiments he made by twiſting magnetiſed wires, and by ſplitting or cleaving them. The effect of the former operation was always to weaken, and ſometimes to invert the verticity; the effect of the latter was ſometimes to change the verticity, and ſometimes not. He likewiſe takes notice of a curious fact, viz. that the orb of the activity of magnets is larger and ſmaller at different times; ſo that the ſame magnet which at one time will exert its influence to the diſtance of nine feet, will at another not extend its operation beyond three feet. From his magnetical experiments and obſervations, Mr. Derham communicated to the Royal Society likewiſe the following curious diſcovery which he has alſo mentioned in the 5th Book of his Phyſico-Theology; viz. "That as the "common horizontal needle is continually va- "rying up and down towards the eaſt and weſt, "ſo is the dipping needle varying up and down "towards or fromwards the zenith, with its "magnetic tendency deſcribing a circle round the "pole of the world, (as the Author conceives,) or "ſome other point. So that if a needle could be "procured ſo nicely made as to point exactly ac-

" cording to its magnetic direction, it would in a
" certain number of years defcribe a circle of about
" 13 gr. radius round the magnetic poles nor-
" therly and foutherly."

3 *Experiments and Obfervations on the Motion of Sounds.* Philofophical Tranfactions, No. 313. In this elaborate and curious paper, which is written in Latin, Mr. Derham endeavours to prove the following propofitions: That the motion of found is not altered by variations in the ftate of the air; though its loudnefs or intenfenefs may be thereby altered: and that founds proceeding from different bodies move all with the fame velocity. He treats of echoes; of the afcending and defcending of founds; of the influence of winds on founds; and of the velocity of winds and of founds.

4. *Account of a Child's crying in Utero.* After having eftablifhed the truth of the fact from various inftances, the Author juftly concludes, that as no found can be uttered without refpiration, fo there muft have been in thofe cafes a temporary refpiration; although he cannot pretend to defcribe the manner in which that may have been performed. " Whether," fays he, " in that refpiration, any

" of

" of the blood paſſeth into the lungs, or whether
" it doth not continue its circulation through the
" *foramen ovale* only; or if any more than ordi-
" nary blood ſhould by ſuch reſpiration get into
" the lungs, whether it may not eaſily and without
" inconvenience be diſcharged thence, during that
" ſtate of life the fœtus leads in the womb; all theſe
" are doubts I am unable to determine. But, how-
" ever, thus much favouring my opinion may be
" obſerved in the ſea-calf, and ſuch other animals
" as have the *foramen ovale*, that the circulation of
" their blood is continued, notwithſtanding the diſ-
" continuance of their reſpiration for a long time."

The Reader will find at the end of this account the titles of the numerous papers with which our Author from time to time enriched the Tranſactions of the Royal Society.

Occupied in theſe moſt laudable purſuits, and diſcharging at the ſame time with unremitting diligence the duties of a faithful Paſtor, Mr. Derham continued to reſide for many years at his living of Upminſter; viſiting London only occaſionally, and even on thoſe evenings when he attended the meetings of the Royal Society, returning on horſe-

back to ſleep at his parſonage. Some of thoſe meteorological papers which he gave to the Philoſophical Tranſactions, indicate, that the obſervations were made during thoſe evening rides between London and Upminſter. Indeed the conſtancy of his reſidence in his own pariſh is demonſtrated by the correct regiſters of the weather which he kept for a courſe of many years, and which are likewiſe to be found in the Tranſactions of the Royal Society.

The life of a country clergyman is in every reſpect more favourable to the cultivation of natural ſcience, by experiment and obſervation, than any other profeſſional employment. He has all the leiſure that is requiſite to philoſophic reſearches; he can watch the ſucceſs of his experiments from day to day, and inſtitute long proceſſes without interruption, or record his obſervations without chaſm or diſcontinuation; and if he aſſociates, as did our excellent Author, and as all philoſophers ought to do, the knowledge of Nature and the diſcovery of her laws, with the perfections and attributes of that wonderful *Being* who framed thoſe laws and conſtantly ſuperintends their operation and effect, he deviates not in any reſpect from his

his profeſſional duties, but is, on the contrary, a moſt uſeful labourer in the vineyard of his heavenly Maſter.

And here we cannot avoid to remark how much more truly conſonant to the character of a clergyman are thoſe reſearches in which this worthy man employed his leiſure hours; reſearches which tend not only to eſtabliſh the truth of the firſt principles of *Religion*, the exiſtence and attributes of the Divinity, but to found that ſentiment upon the beſt affections of the heart, Gratitude and Love towards the Author of our exiſtence, than thoſe occupations which are generally deemed the peculiar province of the clergy, the dark, perplexed, and endleſs controverſies of polemical Theology. It is a certain but a moſt melancholy truth, that although all the fundamental articles of religious belief, which are eſſential to the happineſs of mankind, are in themſelves extremely ſimple, and carry their recommendation both to the underſtanding and affections of the generality of mankind, they have been by the profeſſors and teachers of theology ſo involved in metaphyſical ſubtilty, and ſyſtems of belief ſo diſcordant with each other have thence been reared, that Religion, which

which ought to be the principle of union among mankind, as teaching all to regard themſelves as children of one common benevolent Parent, has too frequently proved the torch of diſſenſion, kindling the moſt malevolent paſſions, which have ſplit ſociety into factions, animated with the moſt rancorous ſpirit againſt each other, and rouſed into action the worſt and moſt implacable feelings of our nature. Religion, ſeparated from Devotion, has become a ſyſtem of the head inſtead of a ſentiment of the heart; and the profeſſed Theologian ſeeks not to engage the affections of man to his Creator, but to gain the praiſe of an able champion, whoſe erudition can put to ſilence the ignorance of his antagoniſts, whoſe ſatire and irony can expoſe them to contempt, or whoſe powerful logic can convict them of ſuch departure from the tenets of orthodoxy, as to render them objects of deteſtation to their fellow-creatures in this world, and hold them forth as victims devoted to everlaſting perdition in that which is to come.

Far different from theſe were the views of religion, and of courſe the occupations of our excellent Author, as theſe his literary labours abundantly ſhew. That he had, indeed, a moſt ſtrict and

and perhaps an over-ſcrupulous ſenſe of the practical duties of the Clerical character, appears from his having thought it neceſſary to uſher in a very uſeful and ingenious work, (one of his earlieſt publications,) intitled *The Artificial Clock-maker*, with the following ſerious apology: "This little "book was a part of the diverſions of the Author's "*juvenile years*, and at firſt drawn up in a rude "manner only to pleaſe himſelf, and divert the "*vacant hours* of a ſolitary country life:" and he adds, "Upon the account of the *innocence* of my "end in publiſhing this book, and that it was "written only as the *harmleſs* (I may add alſo the "*virtuous*) ſport of *leiſure hours*, I think myſelf *ex-"cuſable* to God and the world for the expence of "ſo much time on a ſubject different from my pro-"feſſion."

In 1705 Mr. Derham publiſhed, in three volumes 8vo. "*Miſcellanea Curioſa*, or a Collection "of ſome of the principal Phænomena of Nature "accounted for by the greateſt Philoſophers of "the Age: taken from the Tranſactions of the "Royal Society." In this collection are to be found ſeveral valuable papers of Sir Iſaac Newton, Dr. Halley, Dr. Wallis, M. de Moivre, Mr. Molyneux,

Molyneux, and others; and with regard to their merit, the Editor obſerves, "that the theories and "diſcoveries here collected have already paſſed "the cenſure of the learned world, who have ac-"knowledged them the moſt ſatisfactory accounts "of Nature's proceedings, wherein ſome of her "greateſt depths are fathomed, and a foundation "laid for poſterity to build an infinite ſuperſtruc-"ture." It is probable that our Author intended to have continued this work to a greater length, as he informs us in his Preface, "that the deſign of "the collection is to digeſt, in a convenient method, "all the moſt curious philoſophical and mathema-"tical diſcoveries, as they are to be met with, which "may any way tend to the uſe of life, or advance-"ment of arts and ſciences." But we may preſume he found his plan ſuperſeded by the excellent Abridgment of the Philoſophical Tranſactions by Lowthorpe, Jones, and others, which was ſoon after given to the Public.

In the year 1711 Mr. Derham was choſen by Dr. Teniſon, Archbiſhop of Canterbury, to be the preacher of the Honourable Mr. Boyle's Lectures; an inſtitution which, being frequently ſupplied by men of conſummate ability, has produced a ſeries

a ſeries of diſcourſes equally contributing to the advancement of true Religion and of ſound Philoſophy. This appointment he juſtly conſidered as highly honourable, being a tribute paid both to the reſpectability of his character as a clergyman, and to his talents as a man of ſcience. He bent his mind, therefore, with great vigour and alacrity to the performance of his taſk; and having, as he tells us himſelf, previouſly "tried what he could "do towards the improvement of philoſophical "matters to theological uſes," and made conſiderable collections, yet without any view to publication, he now availed himſelf of theſe materials in the compoſition of *Sixteen Diſcourſes*, of which the object is a demonſtration of the Being and Attributes of God from the works of the Creation. Theſe Diſcourſes he prepared for the preſs, by the addition of a very great number of learned and curious notes; and in 1713, he gave the work to the Public under the title of *Phyſico-Theology.*

In the Preface to this excellent work, the Author, with his uſual modeſty, apologizes to the Public for his own undertaking, conſidering that

they

they were already in poſſeſſion of the writings of ſuch eminent men as Mr. Boyle, Mr. Ray, Dr. Bentley, and others, upon the ſame or nearly ſimilar topics. But with regard to theſe writers, he obſerves, that he had induſtriouſly endeavoured to avoid treading in their footſteps, by forbearing the peruſal of their books for many years, till he had entirely finiſhed his own; and afterwards, on a compariſon of their treatiſes with his, retrenched whatever he found had been treated by them with ſufficient amplitude, and contented himſelf with referring to their authorities: and that in other particulars he had endeavoured to conform, to correct, and clear the obſervations of others. So that on the whole, as the intention of the honourable founder of that inſtitution, which had given birth to theſe Diſcourſes, was, that the ſubject ſhould receive every poſſible illuſtration, by paſſing through different hands, and being treated of in different methods, he humbly hoped that "his per-"formance might be acceptable, though one of the "meaneſt." It is but juſtice to ſay, that this aimable ſelf-humiliation has long ſince met with its ample recompence in the unanimous teſtimony that the world has paid to the ſuperior excellence of that

work,

work, thus meanly rated by its Author, to every thing of the kind that has appeared either before or ſince his time.

In the following year 1714, in the proſecution of the ſame noble and pious deſign, Mr. Derham publiſhed what he had announced in the Preface to the above-mentioned work, his Treatiſe intitled "*Aſtro-Theology*, or a Demonſtration of the Being "and Attributes of God from a Survey of the "Heavens." In this work, which is divided into eight books, the Author treats *firſt* of the magnitude of the univerſe; under which he conſiders not only the meaſure and ſize of the heavenly bodies individually taken, but the immenſity of the whole ſyſtem, the ſpace which it occupies, and the endleſs, or at leaſt incalculable number of planets ſimilar to our own, and in all probability fitted for the reſidence of animated beings, which, if we ſuppoſe each of the fixed ſtars to be the centre of a ſolar ſyſtem like that of which our earth is a component part, make up the wonderful fabric of *the univerſe*. In the *ſecond* Book he treats more particularly of the ſeveral component parts of this grand machine: he aſſigns the reaſons for ſuppoſing each of the fixed ſtars to be a ſun, and the

centre

centre of a ſyſtem of planets; a concluſion, as he ſhews, equally reſulting from phyſical conſiderations, ſuch as their ſhining by their own native light, and not by reflection from our ſun; and alſo from the moral conſiderations of their contributing little or nothing to the uſes of our globe; from the parity and uniformity obſervable in all the works of the Creator; and from the ſuperior recommendation that this theory has to the mind, as giving the moſt extenſive, magnificent, and moſt worthy views of the power and purpoſes of the Almighty Being. In the *third* Book, the Author conſiders the due ſituation and diſtance of the heavenly bodies with reſpect to each other; ſo regulated, as that they neither interfere in their courſes nor in their influences. In the *fourth* Book he treats in a particular manner of the motions of thoſe bodies; of their diurnal and periodical revolutions; and of the perpetuity, conſtancy, and regularity of thoſe motions: and by a parallel drawn between theſe, and the moſt perfect of the works of man, he illuſtrates, in the moſt convincing manner, his fundamental propoſition, that while we allow the latter to be demonſtrable evidence of *deſign*, and of *wiſdom* in the operator, it is either the groſſeſt ſtupidity, or the moſt de-

plorable perverſion of intellect to refuſe to draw the ſame concluſion with reſpect to the former. Our Author, in his *fifth* Book, deduces a further proof of his great theme, from the conſonancy of the heavenly bodies in the ſame ſpherical or ſpheroidal figure, which circumſtance he demonſtrates to ariſe from the univerſal law of Attraction or Gravity; a law which not only determines their globular figure, but preſerves them conſtantly in the ſame figure; thus counteracting that centrifugal force which otherwiſe would cauſe their component parts to ſeparate and fly aſunder. And he here explains, in a ſhort and moſt ſatisfactory manner, that great diſcovery which we owe to the genius of Sir Iſaac Newton; that it is this principle of Gravity which, together with the motion or impulſe originally communicated to theſe bodies by the *Firſt Cauſe*, not only retains the planets in their orbits without the ſlighteſt evagation, but ſolves in the moſt complete manner all the phænomena of their motions. In the *ſeventh* Book the Author treats of the light and heat of the Sun, and of the fixed ſtars; the due poſition of the Sun with reſpect to its planets; of the neceſſity of Light, and the utility of the Atmoſphere; of the Moon and its relative phænomena, the tides, eclipſes, &c.; and of the other ſecondary planets

or

or ſatellites: and he concludes his work in the *eighth* Book, by drawing thoſe practical inferences with reſpect to the relation in which we ſtand to the *Creator*, and the duties we owe him, which naturally reſult from the conſideration of all that has preceded.

This excellent work met with a reception from the public proportionate to its merits, and it has run through numberleſs editions. Much as the ſcience of Aſtronomy has been indebted in detail to modern diſcoveries ſince the time of Mr. Derham, and in particular to thoſe of that moſt eminent and arduous explorer of the heavens, Mr. Herſchel; it is but juſtice to ſay, that all the fundamental principles and material doctrines of the ſcience were as thoroughly underſtood in the age of Sir Iſaac Newton, as they are at the preſent day. The treatiſe of Mr. Derham, therefore, being founded on thoſe ſolid principles, and eſtabliſhed doctrines, is in no ſenſe whatever antiquated: it contains no theories that have been exploded, no facts that more recent obſervation has diſproved. We obſerve, that on ſome points where he has expreſſed his doubt, or rather his uncertainty of opinion, the ſame uncertainty prevails

vails at preſent; as for example, with reſpect to thoſe *nebulous* or cloudy ſtars which are to be found in the conſtellations of *Hercules*, *Orion*, and others, and which our Author, in his Preface to the *Aſtro-Theology*, informs us that he ſurveyed with Mr. Huygens's great glaſs, and frankly owns, that he could never diſcern what they truly were; we know that Mr. Herſchel, within theſe few years, firſt entertained an opinion, that they were analogous to the *milky way*, and that the luminous cloud with which they were ſurrounded was a very crowded cluſter of ſtars exceedingly remote; and afterwards changed that opinion for another, which, though he has rendered probable, is yet by no means ſatisfactorily aſcertained, viz. that the luminous cloud is a ſhining fluid of a nature totally unknown to us, in which the central ſtar is involved.

In the preliminary diſcourſe to the Aſtro-Theology Mr. Derham informs us, that he lay under ſeveral inconveniences for puſhing very far his aſtronomical diſcoveries. One was the want of a free horizon, his dwelling-houſe being much ſurrounded with trees; another was the want of a pole of above 100 feet in length, which was requiſite for raiſing Mr. Huygens's glaſs, of 126 feet,

to

to its proper elevation, ſo as to ſee the heavenly bodies above the thick vapours: but above all, he laments that his increaſing age, and two dangerous fits of ſickneſs, which much impaired his ſight, had rendered him "incapable of ſuch ob-"ſervations, eſpecially at ſuch ſeaſons of the night "and weather as are fitteſt for viewing the hea-"venly bodies." Yet under all theſe diſadvantages his own obſervations appear to have been made with ſingular care and accuracy. It is not unworthy of remark, that he ſeems to have been the firſt who actually ſaw the 6th and 7th ſatellites of Saturn; and although upon further obſervation he was induced to think that this opinion was erroneous, and that what he took for ſatellites were fixed ſtars; yet as Mr. Herſchel has ſince verified the exiſtence of the 6th and 7th ſatellites, it is not improbable that the latter were actually thoſe which Mr. Derham had ſeen with Huygens's teleſcope.

The riſing reputation of our Author, ſoon after the publication of this treatiſe, attracted the notice of the Prince of Wales, afterwards George the Second, who appointed him his Chaplain, and procured for him a canonry of Windſor, into which

which he was inſtalled on the 19th September 1716.

In the years 1713 and 1714, he publiſhed, with large additions from the Author's manuſcripts, ſeveral pieces of his deceaſed friend the learned and ingenious Mr. Ray; particularly his admirable work intitled "The Wiſdom of God manifeſted "in the Works of the Creation;" and "Three "Phyſico-Theological Diſcourſes concerning, "1. The Primitive Chaos and Creation of the "World; 2. The General Deluge, its Cauſes, and "Effects; and, 3. The Diſſolution of the World "and future Conflagration."

In the year 1713, he publiſhed likewiſe a poſthumous work of Mr. Ray's, intitled "*Synopſis* "*Avium et Piſcium*," &c.; and in the year 1718, he methodiſed and publiſhed "Philoſophical Letters "between the late learned Mr. Ray and ſeveral "of his ingenious Correſpondents, Natives and "Foreigners; to which are added thoſe of Francis "Willoughby, Eſquire: the Whole conſiſting of "many curious Diſcoveries and Improvements in "the Hiſtory of Quadrupeds, Birds, Fiſhes, Inſects, "Plants, Foſſils, &c." With reſpect to this work

Mr. Derham informs us in his preface, that he had taken the liberty of abridging many of the letters, by leaving out all that was not ſtrictly philoſophical. This, we muſt be forgiven for obſerving, is a liberty in which an editor ought very rarely to indulge himſelf; and it is probable that, in the preſent inſtance, Mr. Derham would have more gratified the taſte of the generality of his readers, had he publiſhed thoſe letters in their original form, than mutilated as they now appear. Thoſe eminent men, whoſe letters are contained in this volume, would have loſt nothing of the reſpect due to their character as philoſophers, though we had obſerved them in the freedom of epiſtolary correſpondence intermixing their obſervations on ſcience with the ordinary *minutiæ* of life, their domeſtic occupations, the eaſy converſation of the fireſide, or the current ſtory of the day. How little credit do we allow to the faſtidious delicacy of Biſhop *Sprat*, who, while he acknowledged that he was poſſeſſed of a large collection of the letters of *Cowley*, which were ſingularly expreſſive of "the native tenderneſs and innocent gaiety of his mind," yet thought proper to withhold them from the public, becauſe "in ſuch letters the ſouls of men being in a manner

" undreſſed,

"undreſſed, they may in that negligent habit be "fit to be ſeen by one or two in a chamber, but "not to go abroad into the ſtreets."

In the year 1724, Mr. Derham furniſhed a great variety of curious notes and obſervations for *The Natural Hiſtory of Birds and Engliſh Inſects*, in 4 vols. 4to., publiſhed by Mr. *Eleazar Albin*; and in 1726 he publiſhed, after the Author's death, "Philoſophical Experiments and Obſervations of "the late eminent Dr. Robert Hooke, F.R.S., "and Geometry Prof. Greſh., and other eminent "Virtuoſos in his Time."

The laſt work of Mr. Derham's own compoſition which he gave to the public, was "*Chriſto-"Theology*, or a Demonſtration of the Divine "Authority of the Chriſtian Religion; being the "Subſtance of a Sermon preached at Bath on "November 2, 1729, and publiſhed at the earneſt "Requeſt of the Auditory. Lond. 1730, 8vo." And in conſequence of the eminent ſervices he had done both to religion and philoſophy, he received in the ſame year, 1730, the honour of a degree of Doctor in Divinity from the Univerſity of Oxford.

Thus this moſt worthy man ſpent a long and uſeful life, in thoſe ſtudies and occupations which do moſt honour to human nature, the advancement of true religion, and the cultivation of thoſe ſciences that moſt intimately connect man with the Divine Being, by opening to his view, as far as is permitted to finite creatures, the wonderful deſigns and moſt benevolent ends of the Creator. Though of a ſtrong bodily conſtitution, his health had in the latter years of his life begun to decline; and he died in the 78th year of his age, at Upminſter, on the 5th of April 1735.

Dr. Derham was married; but of the name or condition of his wife, the writer of this account has not been able to procure any information. It appears from the ſhort narrative of his life in the *Biographia Britannica*, that he left at leaſt one ſon, Dr. William Derham, who was alive in 1750, and Fellow of St. John's College, Oxford.

In the concluſion of this brief account of the life and writings of this excellent man, it may not be deemed impertinent to ſubjoin a few obſervations touching that ſpecies of Inquiry which forms the ſubject of his principal work, the *Phyſico-Theology*.

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The ſearch of Final Cauſes, or thoſe ends which the great Creator propoſed to himſelf in the formation of the univerſe, and of the various ſpecies of animate and inanimate beings with which it is filled, has been condemned by certain philoſophers on diſtinct and ſeparate grounds of objection. Theſe may be reduced to three principal heads.

1. The poſſibility of tracing deſign from its effects has been altogether denied.

2. It is alleged, that it is preſumptuous and impious in man to pretend, that he is able to diſcover the ends of the Omniſcient Being in the formation of his creatures: and,

3. It is aſſerted, that ſuch reſearches are a hindrance to improvement in philoſophy, and in the knowledge of nature.

The firſt of theſe propoſitions has been maintained by Mr. Hume and his followers; who argue, that the inferences of deſign from its effects are neither demonſtrable by reaſoning, nor deducible from experience. Dr. Reid, who has moſt ably combated Mr. Hume's argument on this ſubject, admits,

admits, that the inferences in queſtion are not the reſult of reaſoning or of experience; but he maintains at the ſame time, that they may be made with a degree of certainty equal to what the human mind is able to attain in any inſtance whatever. "The opinions," ſays a very able philoſopher *, "which we form of the talents of other "men; nay, our belief that other men are intel- "ligent beings; are founded on this very infer- "ence of deſign from its effects. Intelligence and "deſign are not objects of our ſenſes, and yet "we judge of them every moment from external "conduct and behaviour, with as little heſitation "as we pronounce on the exiſtence of what we "immediately perceive." In ſhort, our conviction of the exiſtence of a deſigning cauſe, when we perceive certain regular and conſtant effects, is ſo inborn and natural to the mind, that it may be claſſed among thoſe intuitive truths that need no argument to demonſtrate them. We ſhould juſtly accuſe that man of inſanity, who, on ſeeing a well-conſtructed clock, and obſerving how nicely all its parts were formed and put together, ſo that nothing appeared ſuperfluous and out of place, nor any thing wanting that was neceſſary towards the

* Mr. Prof. Stewart, in his Outlines of Moral Philoſophy.

regularity

regularity of its motion; on finding, likewife, that this beautiful machine anfwered the moft ufeful purpofes of pointing out with the utmoft accuracy the divifion of time by hours, minutes, and feconds, and marked thofe greater divifions by audible founds, fo as to be equally ferviceable in the night as in the day;—we fhould juftly, I fay, accufe that man of abfolute infanity, who fhould deny that thofe various complicated parts were formed and put together for the very purpofes which we fee the machine fo admirably fulfils. It is a law of our nature that we fhould entertain this belief. No man can avoid it. The greateft fceptic himfelf is irrefiftibly impreffed with this belief, and regulates all his actions by fimilar conclufions drawn from effect to caufe.

But, fays the fceptical philofopher, we can in no cafe judge of the wifdom of any defign unlefs we are firft made acquainted with the end or object which the artift propofed to attain; for it is not till we have obtained that acquaintance that we can form any judgment of the means employed to accomplifh the end. Now all that we perceive in the univerfe is, that certain things are actually accom-

accompliſhed; but we are utterly ignorant what plan was propoſed.

In anſwer to this objection we may obſerve, that in many inſtances we perceive with the utmoſt certainty the plan that was propoſed. As for example, we plainly perceive it was the intention of the Creator, that every animated being once formed ſhould be able to perpetuate its kind, ſo that the univerſe may be conſtantly ſupplied with inhabitants without the intervention of the creative power exerted to form every individual animal. This plan is obvious and certain, becauſe we perceive this power of propagation in every individual of every ſpecies of the animal kind, unleſs it is impaired by diſeaſe or accidental defect. In this inſtance we are not left in doubt as to the Creator's plan, and we may therefore boldly reaſon as to the fitneſs or unfitneſs of the means for accompliſhing that end in all the different ſpecies: and if we find theſe means, however various in the different tribes of animals, yet all moſt completely anſwering the ſame end, and with equal certainty accompliſhing one uniform purpoſe, we are compelled to pronounce that this effect is a proof of deſign, and that

that the means are with consummate skill and wisdom adapted to the end.

The second objection that has been urged against all inquiries into Final causes, is, That it is presumptuous and impious in man to endeavour to penetrate into the designs of Providence, and to search out those ends which He proposed to himself in the formation of the universe. This argument is urged by Descartes, who rejects the speculation into Final causes altogether; and we find several observations to the same purpose in the works of Maupertuis and of Buffon.

In answer to this objection we have a single argument of Mr. Boyle, which appears sufficient completely to overthrow it. It were both presumption and folly for man to pretend to know *all* the ends that God might have proposed to himself in the formation of all his works. But to perceive *some* of those ends in certain of his works, is so far from being presumptuous, that it would be absolute blindness and stupidity not to discover them. As for instance, he who considers the complicated structure of the Eye, and how admirably

it ſerves the purpoſes of viſion, or of conveying the knowledge of the figure, ſize, colour, &c. of external objects to the mind, cannot poſſibly entertain a doubt that it was intended for that purpoſe by the Being who framed it; and it would be egregious folly indeed to ſuſpend or to refuſe our belief of that end, from the notion of its being preſumptuous to find out the counſels of the Deity. If a peaſant, ſays Mr. Boyle, were brought into the garden of a philoſopher, and ſhould there obſerve one of thoſe curious gnomonic inſtruments which ſhew at once the place of the Sun in the zodiac, his declination from the equator, the day of the month, the length of the day, &c. it would confeſſedly be preſumptuous in him, while both unacquainted with mathematics and ignorant of the intentions of the artiſt, to pretend to aſcertain *all* the uſes of that elaborate piece of work: but obſerving on it the ordinary marks of a ſun-dial, and ſeeing that the ſhadow actually pointed to the hour of the day, and always indicated it with exactneſs, it would be no preſumption even in this ignorant peaſant to ſay that this, for certain, was *one* of the purpoſes for which the artificer intended it.

In

In addition to this argument it may be obferved, that although the adoption of *fingular* and *uncommon* opinions may be an evidence of prefumption, there can be no prefumption in entertaining opinions in which we are warranted and fupported by the concurring fentiments of mankind. The ufes of many of the works of Nature, and more particularly of many parts of the animal frame, are fo obvious, that they have been acknowledged by all men in all ages of the world. Even the Epicureans, who fuppofed that all things were the operation of Chance, were forced to acknowledge that Chance had conftructed the eye with moft admirable fitnefs for the purpofe of feeing, and the ear for hearing. If, therefore, we perceive thefe purpofes as plainly as the Epicureans, and at the fame time acknowledge that the objects themfelves were the work of an intelligent Artift, it feems a great abfurdity to refufe to believe that this intelligent Artift intended them to ferve thofe ufes and purpofes for which we confefs them to be fo wonderfully adapted. Let us fuppofe any perfon to deny that the eye and ear were intended for feeing and hearing, and to affert that they were defigned for other ufes, we fhould undoubtedly treat that man either with fcorn or pity. But in what refpect

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is the abſurdity the leſs, if, while we cannot aſſign any other purpoſes for which thoſe organs can ſerve, but are forced to acknowledge that they ſerve moſt admirably for ſeeing and hearing, we ſhould yet heſitate to affirm that, for certain, they were intended to ſerve thoſe uſes?

Moreover, it ſeems juſt as unreaſonable to deny that the adaptation of things to certain ends and uſes, is a proof of deſign and wiſdom in the Creator, as it would be to deny that the creation of thoſe things is an evidence of His power. The creation alone of ſuch an infinite variety of beings and ſubſtances, gives certain demonſtration of the wonderful power of God; but that power would be idly diſplayed, if it were not exerted to ends which we muſt acknowledge to be wiſe and beneficent. We might indeed fear a Being of ſuch infinite power, and fear him perhaps the more that we could not perceive his actions to be regulated by any law of wiſdom, or motive of benevolence; but we could not reſpect, adore, or love a Being of this nature. It is the conviction of the perfect wiſdom of the Supreme Being, manifeſted in all the works of the creation, and in their fitneſs to anſwer certain ends, which we acknowledge to be

be benevolent, that entitles this Being to the love and adoration of his creatures *.

With regard to the 3d objection, *viz.* that the search after Final causes is a hindrance to improvement in philosophy, and in the knowledge of nature; this objection seems to have arisen from a misconception of the sentiments of Lord Bacon in that part of his work *de Augmentis Scientiarum*, where he treats of Metaphysics: for Lord Bacon no otherwise condemns the search into Final causes, than in so far as they prevent our investigation into the immediate Physical causes of phænomena. As for instance, if one should ask what is the cause of clouds in the atmosphere? it would no doubt be a very lame and unphilosophical answer to say, That it was to give water to the earth. This indeed is the Final cause; but no philosopher of the present day would rest satisfied with this conviction, while there

* Epicurus ea animis hominum extraxit radicitus religionem, cum Diis immortalibus et opem et gratiam sustulit. Tollit id quod maxime proprium est optimæ et præstantissimæ Naturæ. Quid enim est melius aut quid præstantius bonitate et beneficentia? qua cum carere Deum vultis, neminem Deo carum—neminem ab eo amari, neminem diligi vultis—Quod *si* ita sit, quid veneramur, quid precamur Deos?—Deinde si maximè talis est Deus, ut nulla gratia, nulla hominum caritate teneatur, valeat. Quid enim dicam, propitius sit? esse enim propitius potest nemini.—*Cicero de Nat. Deor.* lib. i. cap. 43, 44.

remain

remain immediate Phyſical cauſes that may be aſſigned for the phænomenon; as, the heat of the ſun raiſing the moiſture from the ſea and earth in the form of vapour. It was no doubt a juſt reproach to many of the antient philoſophers, that, neglecting entirely the inquiry into the immediate Phyſical cauſes of the phænomena of Nature, they reſted ſatisfied with aſſigning the ultimate end or Final cauſe of the phænomena. It was Lord Bacon's intention to explode that indolent and unſatisfying mode of reaſoning, and therefore he was well warranted to ſay that the ſearch of Final cauſes, as generally employed, was *inquiſitio ſterilis, et tanquam virgo Deo conſecrata nihil parit* *. But in the manner that Phyſical ſcience has been cultivated by the moderns, on the ſolid baſis of induction from obſervation and experiment, there is not the ſmalleſt hazard that the inquiry into Final cauſes ſhould retard our progreſs in the ſearch of Phyſical ones. The caveat of Lord Bacon was uſeful in his time; and it has had a moſt beneficial effect; for it is to thoſe admirable methods which he has pointed out that modern Philoſophy is indebted for its moſt material improvements, and Science for its moſt ſublime diſcoveries.

* De Augmentis Scient. lib. iii. c. 5.

It excites no furprife when we obferve the French writers, who are chiefly of the Epicurean fchool, purfuing elaborate inquiries into Nature, with a view only to the difcovery of thofe fecondary caufes which account for her phænomena, without the flighteft regard to that fupreme Intelligence, who has employed thofe fecondary caufes merely as his inftruments in the execution of his infinitely wife and benevolent ends. But it is with much concern we obferve that the example of thofe fceptical writers has been followed by authors who have written with intentions very oppofite to theirs, but who have inadvertently adopted their plan without fully difcerning its purpofe. Thus Dr. Goldfmith, a writer of the beft intentions, who has compofed a Natural Hiftory, chiefly from materials furnifhed by the French writers, fets out after their example with a denunciation of the mifchievous confequences refulting to philofophy from the fpeculation into Final caufes; though in the courfe of his work the natural bias of his mind occafionally appears, in pointing out in ftrains of the warmeft eloquence to our obfervation, thofe very ends of wifdom and of benevolence, whofe confideration he had before exploded as ufelefs, and even pernicious to the profecution of fcience. Thus, in the fourth

chapter of the firſt volume of his *Hiſtory of the Earth and animated Nature*, he retails the miſunderſtood remark of Bacon; that "the inveſtiga-"tion of final cauſes is a barren ſtudy; and like "a virgin dedicated to the Deity brings forth no-"thing." Yet in the laſt chapter of the ſame volume he conſiders "the univerſe as the palace in "which the Deity reſides, and this earth as one "of its apartments, allotted to man for his habit-"ation and the ſcene of his enjoyments;" he ſees "the immenſe and ſhapeleſs maſs of matter "formed into worlds by the power of the Deity, "and diſperſed at intervals to which even the ima-"gination cannot travel." He diſcerns the earth at his command "producing by its twofold mo-"tion the change of ſeaſons, and the grateful viciſ-"ſitudes of day and night."—He obſerves it "with a ſteady rotation ſucceſſively preſenting "every part of its boſom to the ſun; at once im-"bibing nouriſhment and light from that parent of "vegetation and fertility." He remarks "the "waters on its ſurface ſupplied in healthful abun-"dance to ſupport life and aſſiſt vegetation: the "mountains ariſing to diverſify the proſpect and "give a current to the ſtream: the ſeas extending "from one continent to another, repleniſhed with "animals

" animals that may be turned to human ſupport, " and alſo ſerving to enrich the earth with a ſuffi- " ciency of vapour—breezes flying along the ſur- " face of the fields to promote health and vegeta- " tion—the coolneſs of the evening that invites " man to his reſt, and the freſhneſs of the morn- " ing that renews him for his labour." Thus this moſt eloquent writer, in contempt of that law which he had impoſed of baniſhing final cauſes entirely from his ſpeculations, unconſciouſly re- ſorts to them whenever his ſubject points the way, and yields himſelf without reſerve to that emotion of gratitude which is felt by every well-conſtituted mind to the bountiful Author of all its multiplied enjoyments.

It is curious to remark the Epicureans them- ſelves, who utterly diſclaim a Divine Providence as concerned either in the original formation or in the government of the univerſe, are yet forced to acknowledge through the whole ſyſtem the moſt pregnant and uncontrovertible marks of benevo- lent deſign. But how do they extricate themſelves from this apparent dilemma? Why, by beſtowing even on inſenſate and brute matter that eulogium which they withhold from the Divinity. Thus

 Pliny,

Pliny, who acknowledged no God as the author of all the wonders to which he ſolicits our attention in his Natural Hiſtory, indulges a vein of the moſt eloquent panegyric on the *Benevolence* of the *Earth* to man. " It is this Earth," ſays he, " that like
" a kind mother receives us at our birth, and ſuſ-
" tains us when born. It is this alone of all the ele-
" ments around us that is never found an enemy to
" man. The waters deluge him with rains, oppreſs
" him with hail, and drown him with inundations.
" The air ruſhes in ſtorms, prepares the tempeſt or
" lights up the thunders; but the Earth, gentle and
" indulgent, ever ſubſervient to the wants of man,
" ſpreads his walks with flowers, and his table with
" plenty; returns with intereſt every good com-
" mitted to her care; and though ſhe produces the
" poiſon, ſhe ſtill ſupplies the antidote; though
" conſtantly importuned more to furniſh the luxu-
" ries of man than his neceſſities, yet even to the
" laſt ſhe continues her kind indulgence; and when
" life is over, ſhe piouſly covers his remains in her
" boſom *." Thus even the Atheiſt plainly diſcerns in the ſyſtem of Nature the traces of benevolent deſign; but, *inſanientis ſapientiæ conſultus*, proficient only in that wiſdom which is the pride of fools, he

* Plin. Hiſt. Nat. lib. ii. cap. 63.

attributes

attributes that design and that benevolence to a substance incapable itself of thought or purpose of any kind, and stupidly transfers the praise due to the Creator, to the inert, the lifeless, and unconscious *substratum* of his operations.

With the true philosopher, the research into Physical causes and Final ones will ever go hand in hand; and indeed in most sciences there would be a very great bar to improvement, if we were to attempt to separate them. Let the science of Anatomy be taken as an example. We study the structure of the different parts of the human body, with a constant view to the functions which those parts are intended to serve; nay the very end of the study is in order that we may be able to correct any fault or unfitness of the organs, and to restore them to that healthful tone which is necessary for the right performance of their functions. We anatomise the eye, and examine its different tunicles and coats, that we may be enabled to find a cure for imperfect vision, or for absolute blindness. We examine the structure of the stomach and bowels, that we may well understand what state of these organs is best fitted for perfect digestion and conversion of the aliment into chyle and blood, and know how to restore that state when impaired by accidental

injury, or vitiated by diſeaſe. In ſhort, it may be confidently affirmed, that in this ſcience, which is nothing more than the perfect knowledge of the animal machine, we could no more advance a ſingle ſtep without having in our view the proper functions of the ſeveral parts of that machine, than we could ſtudy the art of clock-making without having it in our view that all the parts of the machine were intended to operate towards one ultimate or final purpoſe, the regular diviſion of time by hours, minutes, and ſeconds. In like manner there is ſo neceſſary a connection between the ſcience of Medicine and Final cauſes, that they may be conſidered as abſolutely inſeparable; and it may be affirmed in general, that in the ſtudy of all thoſe ſciences which have for their object the knowledge of nature, the ſearch of Final cauſes, or of thoſe wiſe ends propoſed by the Author of Nature, is altogether as neceſſary, as an attention to the views and purpoſes of man is neceſſary in ſtudying thoſe arts which are dependent on human wiſdom and ſkill; as for example, architecture, ſhip-building, the conſtruction of machines, &c.

Laſtly, it may be obſerved that the greateſt philoſophers, far from excluding from their ſpecula-

tions

tions the refearch into Final caufes, have recommended that refearch as the greateft incentive to the profecution of fcience, and as being eminently ferviceable in guiding or conducting our inquiries. With regard to the former of thefe purpofes, what motive can be more worthy of an intelligent being, what end more animating to his refearches, than the earneft defire of tracing out the footfteps of Almighty goodnefs; of exploring thofe characters of infinitely wife defign, which to a certain degree are obvious, even to the moft fuperficial obferver, but of whofe univerfality, extent, and wonderful connection, through the whole of this vifible fyftem of nature, the philofopher alone can form an adequate comprehenfion? With refpect to the latter purpofe, the guiding or conducting our inquiries, Mr. Boyle has recorded a very ftriking teftimony of the utility of fuch fpeculations. "I remember," fays he, "that when I afked our famous Harvey what "were the things that induced him to think of a "circulation of the blood? he anfwered me, that "when he took notice that the valves in the veins "in fo many parts of the body were fo placed, that "they gave a free paffage of the blood towards the "heart, but oppofed the paffage of the venal blood "the contrary way, he was invited to imagine

"that

"that ſo provident a cauſe as Nature had not "placed ſo many valves without deſign; and no "deſign ſeemed more probable than that, ſince "the blood could not well, becauſe of the inter- "poſing valves, be ſent by the veins to the limbs, "it ſhould be ſent through the arteries, and return "through the veins, whoſe valves did not oppoſe "its courſe that way." Thus the conſideration of the Final cauſe actually led to the diſcovery of the Phyſical truth.

Another beautiful example of the utility of attending to Final cauſes in the proſecution of ſcience, is to be found in the *Elementa Catoptricæ & Dioptricæ Sphæricæ* of the celebrated David Gregory, Savillian Profeſſor of Aſtronomy at Oxford. In the end of this treatiſe is an obſervation which ſhews that what is generally believed to be a diſcovery of a much later date, the conſtruction of achromatic teleſcopes, which was firſt actually put in practice by Mr. Dollond, and has ſince been brought to great perfection by that ingenious artiſt, and by Mr. Ramſden, had ſuggeſted itſelf to the mind of David Gregory, "from the reflection on the admirable "contrivance of Nature, who does nothing without "an uſeful purpoſe, in combining the different

"humours

" humours of the eye. " *Quod ſi ob difficultates*
" *phyſicas in ſpeculis idoneis torno elaborandis et po-*
" *liendis, etiamnum lentibus uti oporteat, fortaſſis me-*
" *dia diverſæ denſitatis ad lentem objectivam compo-*
" *nendam adhibere utile feret, ut a natura factum*
" *obſervamus in oculi fabrica, ubi chriſtallinus humor*
" *(fere ejuſdem cum vitro virtutis ad radios lucis*
" *refringendos) aqueo et vitreo (aquæ quoad refrac-*
" *tionem haud abſimilibus) conjungitur, ad imaginem*
" *quam diſtinctè fieri poterit, a Natura nihil fruſtra*
" *moliente, in oculi fundo depingendam* *."—" But
" if, on account of the phyſical difficulties which
" we meet with in turning and poliſhing the larger
" *ſpecula* of teleſcopes, we are forced ſtill to make
" uſe of lenſes, it might perhaps be of advantage,
" in framing the object-glaſſes of our teleſcopes, to
" employ the combination of *media* of different
" denſity; as we obſerve is done by Nature in the
" ſtructure of the eye; in which the chryſtalline
" humour, poſſeſſing nearly the ſame refracting
" power with glaſs, is conjoined with the aqueous
" and vitreous humours, which have a refracting
" power ſimilar to water; a combination, which

* Catopt. & Deopt. Sphær. Elem, Oxon. 1695. p. 98. See Life of Dr. John Gregory, prefixed to his works. Edinburgh, 1788.

" Nature,

“ Nature, who does nothing in vain, has found to
“ be the fitteſt for painting with the greateſt poſ-
“ ſible diſtinctneſs the figure of objects on the *re-*
“ *tina*.”

Through the whole works of the immortal Newton, we perceive a conſtant attention to Final cauſes, or to the great purpoſes of the Deity. It was the firm opinion of this moſt eminent philoſopher, that as we are every where encountered in our reſearches by powers and effects which are unaccountable upon any principles of mere mechaniſm, or the combinations of matter and motion, we muſt for ever reſort to a ſupreme power, whoſe influence extends over all Nature, and who accompliſhes the wiſeſt and moſt benevolent ends by the beſt poſſible means. Of his ſentiments on this ſubject, his excellent abridger and commentator, Mr. Maclaurin, gives the following brief detail, with which we ſhall cloſe the ſubject.

“ There is nothing we meet with more fre-
“ quently and conſtantly in Nature, than the traces
“ of an all-governing Deity. And the philoſopher
“ who overlooks theſe, contenting himſelf with the
“ appearances of the material univerſe only, and the
“ mechanical

" mechanical laws of motion, neglects what is moſt " excellent; and prefers what is imperfect to what " is ſupremely perfect, finitude to infinity, what is " narrow and weak to what is unlimited and al- " mighty, and what is periſhing to what endures " for ever. Such who attend not to ſo manifeſt " indications of ſupreme wiſdom and goodneſs, " perpetually appearing before them wherever they " turn their views or inquiries, too much reſemble " thoſe antient philoſophers who made *Night*, *Mat-* " *ter*, and *Chaos*, the original of all things.

" The plain argument for the exiſtence of the " Deity, obvious to all, and carrying irreſiſtible " conviction with it, is from the evident contri- " vance and fitneſs of things for one another, " which we meet with throughout all parts of the " univerſe. There is no need of nice or ſubtle " reaſonings in this matter: a manifeſt contrivance " immediately ſuggeſts a contriver. It ſtrikes us " like a ſenſation; and artful reaſonings againſt it " may puzzle us, but it is without ſhaking our be- " lief. No perſon, for example, who knows the " principles of Optics, and the ſtructure of the eye, " can believe that it was formed without ſkill in " that ſcience; or that the ear was formed with-

" out

" out the knowledge of ſounds; or that the male
" and female of animals were not formed for each
" other, and for continuing the ſpecies. All our
" accounts of Nature are full of inſtances of this
" kind. The admirable and beautiful ſtructure of
" things for Final cauſes, exalts our idea of the *Con-*
" *triver*: the unity of deſign ſhews him to be
" *One*. The great motions in the ſyſtem performed
" with the ſame facility as the leaſt, ſuggeſt his *Al-*
" *mighty Power*, which gave motion to the earth
" and the celeſtial bodies, with equal eaſe as to the
" minuteſt particles. The ſubtilty of the motions
" and actions in the internal parts of bodies, ſhews
" that his influence penetrates the inmoſt receſſes of
" things, and that He is equally *active* and *preſent*
" every where. The ſimplicity of the laws that
" prevail in the world, the excellent diſpoſition of
" things, in order to obtain the beſt ends, and the
" beauty which adorns the works of Nature, far
" ſuperior to any thing in art, ſuggeſt his conſum-
" mate *Wiſdom*. The uſefulneſs of the whole
" ſcheme, ſo well contrived for the intelligent
" beings that enjoy it, with the internal diſpoſition
" and moral ſtructure of thoſe beings themſelves,
" ſhew his unbounded *Goodneſs*. Theſe are the
" arguments which are ſufficiently open to the views
" and

" and capacities of the unlearned, while at the fame " time they acquire new ftrength and luftre from " the difcoveries of the learned *."

Such were the fentiments of the great Newton on the fubject of Final caufes: and we cannot fail to remark that the preceding detail of thofe fentiments by Mr. Maclaurin, is in fact a brief but complete delineation of Mr. Derham's views in his principal works, the *Phyfico-Theology* and *Aftro-Theology*.

With refpect to this new Edition of the Phyfico-Theology now offered to the Public, it may be proper here to add a few words. The fole motive to this undertaking, on the part of the Editor, was an earneft defire to extend the benefit and utility of this admirable work to all claffes of readers, by opening to their view, what is in reality the moft interefting as well as amufing part of the book, thofe copious ftores of phyfical knowledge, the facts and obfervations contained in the notes to this work. Separated

* Account of Sir Ifaac Newton's Philofophical Difcoveries, by Colin Maclaurin, A. M. F. R. S. Book iv. c. 9.

indeed

indeed from the notes, the text of the Phyſico-Theology is nothing elſe than a detail of doctrines without their proofs; which the reader muſt content himſelf with receiving on the bare authority of their announcer. This, however, was by no means the intention of the author; for in reality he has ſupported every obſervation which he advances in the text, by ample proofs and illuſtrations contained in the notes. As theſe, however, conſiſt in great part of quotations from Latin and Greek authors, the unlearned reader is totally excluded from all the benefit of the proofs and illuſtrations drawn from their works. It appeared therefore to the Editor, that a faithful tranſlation of thoſe quotations in the learned languages could not fail to be acceptable, not only to ſuch readers as are entirely ignorant of thoſe languages, but even to thoſe who, though moderately ſkilled in them, are not verſant in the technical and ſcientific phraſeology uſed by the Latin and Greek writers. Another obvious mean of extending the utility of this excellent work was, to ſubjoin a ſhort notice of all the moſt important diſcoveries that have been made in Phyſics ſince the time of Mr. Derham; as well as of ſuch curious facts as have recently come to knowledge, and which tend to confirm the chief

doctrines, or to throw additional light on the principal topics of the author's inquiry. This therefore the Editor has attempted in the additional Notes, which are pretty numerous and ample: and he has likewiſe ſupplied what was confeſſedly a moſt material want in all former editions, ſeveral Plates, to illuſtrate thoſe ſubjects which are imperfectly underſtood by verbal deſcription alone. If in all, or in any of theſe reſpects, this new edition of the Phyſico-Theology ſhall be deemed worthy of the attention of the Public, the Editor is well rewarded, in the pleaſing conſciouſneſs of having contributed his aid to the advancement of thoſe noble purpoſes of its pious Author, who,

> ——to the height of this great argument,
> Sought to aſſert Eternal Providence,
> And juſtify the ways of God to man!

A

CATALOGUE

OF THE

WORKS of the Rev. Dr. W. DERHAM.

Physico-Theology, or a Demonſtration of the Being and Attributes of God, from his Works of Creation. Lond. 1713.

Aſtro-Theology, or a Demonſtration of the Being and Attributes of God, from a Survey of the Heavens. Illuſtrated with Copperplates. 8vo. 1714.

Chriſto-Theology, or a Demonſtration of the Divine Authority of the Chriſtian Religion; being the Subſtance of a Sermon preached at Bath, 2d November 1729.

The Artificial Clock-Maker, a Treatiſe of Watch and Clock Work; ſhewing to the meaneſt Capacities the Art of calculating Numbers to all Sorts of Movements, &c.; with the ancient and modern Hiſtory of Clock-Work, and many Inſtruments, Tables, and other Matters, &c. This was re-publiſhed with large Emendations in 1734.

Notes and Obſervations ſubjoined to the Natural Hiſtory of Birds and Engliſh Inſects; by Eleazar Albin. 4 vols. 4to.

Papers in the Philofophical Tranfactions, *viz.*

1. Part of a Letter dated Dec. 6, 1697, giving an Account of fome Experiments about the Height of the Mercury in the Barometer, at Top and Bottom of the Monument in London; and a Defcription of a portable Barometer. Phil. Tran. No. 236. p. 2, &c.

2. A Letter dated January 13, 1697-8, about a Contrivance to meafure the Height of the Mercury of the Barometer, by a Circle on one of the Weather Plates: with a Regifter or Diary of the Weather, obferved every Day at Upminfter, during the Year 1697. Ibid. No. 237. p. 45.

3. A Letter to Dr. Sloane, with a Regifter of the Weather, Winds, Barometer's Height, and Quantity of Rain falling at Upminfter in Effex, during the Year 1698. Ibid. No. 249. p. 45, &c.

4. A Regifter of the Weather, &c. as above, for the Year 1699. Ibid. No. 262. p. 527.

5. Obfervations on the Death-Watch; or that Infect which makes a Noife like the Beats of a Watch. Ibid. No. 271. p. 832.

6. Obfervations on the Weather, Rain, Winds, &c. for 1699, 1700, 1701, 1702, compared with other Obfervations made at Townley in Lancafhire by Mr. Townley, and communicated to Mr. Derham. Ibid. No. 286. p. 1443.

7. An Account of fome Spots obferved in the Sun in June 1703. Ibid. No. 288. p. 1504.

8. Obfervations on the great Storm, November 26, 1703. Ibid. No. 289. p. 1530.

9. The Hiftory of the Death-Watch. Ibid. No. 291. p. 1586.

10. Account of an Inftrument for finding the Meridian, with a Defcription of the fame. Ibid. No. 291. p. 1578.

11. Ex-

11. Experiments on the Motion of Pendulums *in vacuo*, Phil. Tran. No. 294. p. 1785.

12. A Profpect of the Weather, Winds, and Height of the Mercury in the Barometer on the firft Day of the Month, and of the whole Rain in every Month in the Year 1703 and the Beginning of 1704. Obferved at Townley in Lancafhire by R. Townley Efq. and at Upminfter in Effex by William Derham. Ibid. No. 297. p. 1877.

13. Magnetical Experiments and Obfervations. Ibid. No. 303. p. 2136.

14. Account of a Glade of Light feen in the Heavens, 20th March 1705-6. Ibid. No. 305. p. 2220.

15. Tables of the Weather, &c. for the Year 1705. Ibid. No. 309. p. 2378.

16. Account of a Pyramidal Appearance in the Heavens, feen in Effex, April 3, 1707. Ibid. No. 309. p. 2378.

17. Experiments and Obfervations on the Motion of Sounds, in Latin. Ibid. No. 313. p. 2.

18. On the Migration of Birds. Ibid. No. 315. p. 123.

19. Account of an Eclipfe of the Sun, Sept. 3, 1708, as obferved at Upminfter. Ibid. No. 320. p. 312.

20. Account of an Eclipfe of the Moon, Sept. 18, 1708, Ibid.

21. Account of a ftrange Meteor, or *Aurora Borealis*, in September or October 1706. Ibid. p. 310.

22. An Account of a Child's crying in the Womb. Ibid. No. 324. p. 485.

23. The Hiftory of the great Froft in 1708. Ibid. p. 454.

24. Account of Spots obferved in the Sun from 1703 to 1708. Ibid. No. 330.

25. Account of the fame from 1707 to 1711. Phil. Tran. p. 278.

26. Of fubterraneous Trees found at Dagenham-Breach in Effex. Ibid. No. 335. p. 478.

27. Account of an Eclipfe of the Moon feen at Upminfter, January 12, 1711-12. Ibid. No. 336. p. 522.

28. Of a Woman big with Child, and having the Small-pox, delivered of a Child having the fame Diftemper, September 8, 1713. Ibid. No. 337. p. 165.

29. An Account of the Rain at Upminfter for 18 Years. Ibid. No. 341. p. 130.

30. Tables of the Barometrical Altitudes for 1708, at Zurich in Switzerland; and of the Rain at Pifa in Italy, and Zurich, and Upminfter, for 1707, 1708; with Remarks on the Winds, Heat, and Cold, &c. Ibid. p. 342.

31. Mifchiefs occafioned by fwallowing the Stones of Bullace and Sloes. Ibid. No. 349. p. 484.

32. Extracts from Mr. Gafcoigne's and Mr. Crabtrie's Letters, proving Mr. Gafcoigne to have been the Inventor of the Telefcopic Sights of Mathematical Inftruments, and not the French. Ibid. No. 352. p. 603.

33. Obfervations about Wafps, and the Difference of their Sexes. Ibid. No. 382. p. 53.

34. Obfervations on the *Lumen Boreale*, or Streaming, on October 8, 1726. Ibid. No. 398. p. 245.

35. Tables of the Eclipfes of Jupiter's Satellites from 1700 to the Year 1727; with Remarks on thofe Tables. Ibid. No. 402. p. 415.

36. The Difference in Time of the Meridians of different Places, computed from Obfervations of the Eclipfes of Jupiter's Satellites. Ibid. No. 407. p. 33.

37. A Letter to Sir Hans Sloane, R. S. Pr. Containing a Defcription of fome uncommon Appearances in an *Aurora Borealis*, Oct. 13, 1728. Phil. Tran. No. 410. p. 137.

38. Of the Meteor called *Ignis Fatuus*, (Will of the Wifp,) from Obfervations made in England, by Mr. Derham, and others in Italy, communicated by Sir Thomas Dereham, Bart. Ibid. No. 411. p. 204.

AN

ANALYSIS

OF THE

FOLLOWING WORK.

VOL. I.

THE works of the creation relating to our terraqueous globe, are ſuch as are viſible in the

Outworks or appendages of the globe, *viz.* theſe three:

2. Light.

Various

Situation

Geometrically

VOL. II.

different

Materials

Having in the Fourth Book thus difpatched the decad of things in common to the *fenfitive creatures*, I take a view of their particular tribes, *viz.* of

Various

The

Placed

The

Two,

Poiſon,

The

A SUR-

A
SURVEY
OF THE
TERRAQUEOUS GLOBE.

INTRODUCTION.

IN *Pſal.* cxi. 2. the Pſalmiſt aſſerts, That *the* (*a*) *works of the Lord are great; ſought out of all them that have pleaſure therein.* This is true of all *God's works*, particularly of his *works of Creation:*

(*a*) It is not unlikely that the Pſalmiſt might mean, at leaſt have an eye to, *the works of the creation* in this text, the word מעשה being the ſame that in *Pſal.* xix. 1. is tranſlated *God's handy-work*, which is manifeſtly applied to the works of *creation*, and properly ſignifieth *factum, opus, opificium*, from עשה *fecit, paravit, aptavit.* And ſaith *Kircher*, *Significat talem affectionem, quâ aliquid exiſtit vel realiter, vel ornatè, vel ut non ſit in priſtino ſtatu quo fuit.*—" Signifies that mode by which a thing exiſts, either as the ſchoolmen ſay *really* or *ornately*, or is at preſent in a ſtate in which it formerly was not."—*Concord.* p. 2. col. 931.

which when *fought out;* or, as the *Hebrew* word (*b*) fignifieth, when *heedfully* and *deeply pried into, folicitoufly obferved and inquired out*, efpecially when clearly difcovered to us; in this cafe, I fay, we find thofe works of God abundantly to deferve the Pfalmift's character of being *great* and noble; inafmuch, as they are made with the moft exquifite art (*c*), contrived with the utmoft fagacity, and ordered

(*b*) דרש *Quæfivit, perquifivit, fcifcitatus eft.* Buxtor. in verb. *Et fimul importat curam & folicitudinem.*—"Sought out, inquired; and it imports likewife care and folicitude."—*Conrad. Kirch.* ib. p. 1, col. 1174.

(*c*) *Quod fi omnes mundi partes ita conftitutæ funt, ut neque ad ufum meliores potuerint effe, neque ad fpeciem pulchriores: videamus utrùm ea fortuita fint, an eo ftatu, quo cohærere nullo modo potuerint, nifi fenfu moderante divinâque providentiâ. Si ergo meliora funt ea quæ naturâ, quàm illa, quæ arte perfecta funt, nec ars efficit quid fine ratione; ne natura quidem rationis expers eft habenda. Qui igitur convenit, fignum, aut tabulam pictam cùm adfpexeris, fcire adhibitam effe artem; cumque procul curfum navigii videris, non dubitare, quin id ratione atque arte moveatur: aut cùm folarium, &c. mundum autem, qui & has ipfas artes, & earum artifices, & cuncta complectatur, confilii & rationis effe expertem putare? Quod fi in Scythiam, aut in Britanniam, fphæram aliquis tulerit hanc, quam nuper familiaris nofter effecit Pofidonius, cujus fingulæ converfiones idem efficiunt in fole, &c.—quod efficitur in cælo, fingulis diebus & noctibus; quis in illâ barbarie dubitet, quin ea fphæra fit perfecta ratione? Hi autem dubitant de mundo, ex quo & oriuntur, & fiunt omnia, cafune ipfe fit effectus,—an ratione, an mente divinâ? Et Archimedem arbitrantur plus valuiffe in imitandis fphæræ converfionibus, quàm naturam in efficiendis, præfertim cùm multis partibus fint illa perfecta, quam hæc fimulata, folertius, &c.*—"Wherefore, fince all the parts of this earthly fabric are fo conftituted as to manifeft at once the greateft degree of utility and the moft confummate beauty, let us confider whether this wonderful aptitude could have been the refult of chance, or muft have been effected by

ordered with plain wife defign, and miniftering to admirable ends *. For which reafon St. *Paul*

by a fupreme over-ruling intelligence. If it is admitted that the works of nature are fuperior to thofe of art; and yet art does nothing but in confequence of thought and reafon; how can we fuppofe a principle called nature, which yet is devoid of reafon? Pictures and ftatues are allowed to be the effect of defign and fkill in the artift: when we fee a fhip cutting her way through the pathlefs ocean, we fuppofe immediately that fhe is governed by a fkilful pilot;—and fhall the world itfelf, that immenfe machine which comprehends all arts and artifts, and every object of thought or fkill, be deemed to refult from no intelligent or reafoning principle? If a perfon fhould carry into the remote regions of Scythia or Britain that fphere made by our friend Pofidonius, which fo ingenioufly fhews the various motions of the heavenly bodies, would there be a fingle man in thofe barbarous nations fo grofsly ignorant as to doubt that the machine was made by art? Yet our pretenders to reafon fhall doubt whether this world arofe from chance or from intelligence. They admire the art of Archimedes in conftructing a machine to reprefent the motions of the celeftial orbs; without acknowledging reafon or art in HIM who framed thofe orbs themfelves and put them in motion."—*Cic. de Nat.* l. ii. c. 34, 35.

* "The man," fays Dr. Beattie, "who fhould fuppofe a large city confifting of a hundred thoufand palaces, all finifhed in the minuteft parts, and furnifhed with the greateft elegance and variety of ornament, and with all forts of books, pictures, and ftatues, executed in the moft ingenious manner, to have been produced by the accidental blowing of winds and rolling of fands, would juftly be accounted irrational. But to fuppofe the universe, or our folar fyftem, or this earth, to be the work of undefigning chance, is an abfurdity incomparably greater."—*Elements of Moral Science*, part ii. ch. 1. EDITOR.

might well affirm of those Ποιήματα of God (*d*), That the *invisible things of God, even his eternal power and Godhead, are understood by them.* And indeed they are the most easy and intelligible demonstrations of the *being* and *attributes* of God (*e*); especially to such as are unacquainted with the subtilties of reasoning and argumentation; as the greatest part of mankind are.

It may not therefore be unsuitable to the nature and design of lectures (*f*) founded by one of the greatest virtuoso's of the last age, and instituted too on purpose for the proof of the Christian religion against atheists, and other infidels, to improve this occasion in the demonstration of the *being* and

(*d*) And a little before he saith of *nature* itself, *Omnem ergo regit naturam ipse* [Deus] *&c.*—"God himself governs all nature."

(*e*) *Mundus codex est Dei, in quo jugiter legere debemus.*—"The world is the great volume of God, in which we ought continually to read."—*Bernard. Serm.*

Arbitror nullam gentem, neque hominum societatem, apud quos ulla Deorum est religio, quidquam habere sacris Eleusiniis aut Samothraciis simile. Ea tamen obscurè docent quæ profitentur: naturæ verò opera in omnibus animantibus sunt perspicua.—"I suppose there is no nation or society of men who profess a reverence for the Gods, among whom there are any institutions like those of the Eleusinian or Samothracian mysteries. Yet these teach but obscurely the doctrines which they profess to inculcate: the artifice of nature is conspicuous in the formation of all animal substances."—*Galen. de Us. Part.* l. xvii. c. 1.

(*f*) *Philosophia est catechismus ad fidem.*—"Philosophy is the catechism which instructs us in our faith."—*Cyril.* 1. *contr. Jul.*

attributes

attributes of an infinitely wife and powerful Creator, from a curfory furvey of the works of *creation*, or (as often called) of *nature*.

Which works belong either to our *Terraqueous Globe*, or the *Heavens*.

I fhall begin with our *own Globe*, being neareft, and falling moft under our fenfes. Which being a fubject very various and copious, for the more methodical and orderly proceeding upon it, I fhall diftribute the works therein,

I. Into fuch as are not properly Parts, but *Appendages* or *Out-works* of the Globe.

II. The *Globe* itfelf.

BOOK I.

Of the Out-works of the Terraqueous Globe; the Atmoſphere, Light, and Gravity.

CHAP. I.

Of the Atmoſphere in general.

THE atmoſphere, or maſs of air, vapours and clouds, which ſurrounds our globe, will appear to be a matter of deſign, and the infinitely wiſe Creator's work, if we conſider its *nature* and *make* (*a*), and its *uſe* to the world (*b*).

1. Its nature and make, a maſs of air, of ſubtile penetrating matter, fit to pervade other bodies, to penetrate into the inmoſt receſſes of nature, to excite, animate, and ſpiritualiſe; and in ſhort, to

(*a*) *Mundi pars eſt aer, & quidem neceſſaria: hic eſt enim qui cœlum terramque connectit, &c.*—"The air is a neceſſary part of our ſyſtem. It connects the heavens and the earth."—*Senec. Nat. Qu.* l. ii. c. 4.

(*b*) *Ipſe aer nobiſcum videt, nobiſcum audit, nobiſcum ſonat; nihil enim eorum ſine eo fieri poteſt, &c.*—"Without the air we could neither ſee, hear, nor communicate ſounds."—*Cic. de Nat. Deor.* l. ii. c. 33.

be the very ſoul of this lower world. A thing conſequently,

2. Of greateſt uſe to the world, uſeful to the life, the health, the comfort, the pleaſure, and buſineſs of the whole globe. It is the air the whole animal world breatheth, and liveth by; not only the animals inhabiting the earth (*c*) and air,

(*c*) As the air is of abſolute neceſſity to animal life, ſo it is neceſſary that it ſhould be of a due temperament or conſiſtence; not foul, becauſe that ſuffocateth; not too rare and thin, becauſe that ſufficeth not: with examples of each of which, I ſhall a little entertain the reader. In one of Mr. *Hawkſbee*'s compreſſing engines, I cloſely ſhut up a *ſparrow*, without forcing any air in; and in leſs than an hour the bird began to pant, and be agitated; and in leſs than an hour and half to be ſick, vomit, and more out of breath; and in two hours time was nearly expiring.

Another I put in and compreſſed the air, but the engine leaking, I frequently renewed the compreſſure; by which means, (although the bird panted a little after the firſt hour,) yet after ſuch frequent compreſſures, and emiſſion of freſh air, it was very little concerned, and taken out ſeemingly unhurt after three hours.

After this I made two other experiments in compreſſed air, with the weight of two atmoſpheres injected, the engine holding tight and well; the one with the *great tit-mouſe*, the other with a *ſparrow*. For near an hour they ſeemed but little concerned; but after that grew fainter, and in two hours time ſick, and in three hours time died *. Another thing I took notice

* With regard to the weight of the atmoſphere, it is aſcertained that every ſquare inch of ſurface ſuſtains a preſſure of 15 pounds. Every ſquare foot, therefore, containing 144 inches, muſt

air (*d*), but thoſe of the waters (*e*) too. Without it
moſt

tice of, was, that when the birds were ſick, and very reſtleſs, I fancied they were ſomewhat relieved for a ſhort ſpace, with the
motion

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muſt ſuſtain a preſſure of 2160; and if we ſuppoſe a man's body to contain 15 ſquare feet of ſurface, which is near the truth, at an average of the medium ſize of the human body, then it is demonſtrable he muſt ſuſtain a weight of 32,400 pounds or 16 ton. This enormous preſſure would cruſh us in a moment, were it not balanced by the air or elaſtic fluids contained in all parts of the body. And as the atmoſpherical preſſure varies very much at different times and in different ſituations, even to the weight of a ton of difference, it is thence evident that the ſpring of the elaſtic fluid in our bodies, muſt in a wonderful manner keep pace in its variation with the weight of the atmoſphere. It is remarked that in all caſes it ſeems to keep pace with it when the preſſure is naturally diminiſhed, and even when it is artificially augmented, but not when it is artificially diminiſhed. In that kind of weather when the preſſure of the air is leaſt, or at the tops of mountains, we never perceive our veins to ſwell; but on the contrary in the latter caſe, when the preſſure is very much diminiſhed, we feel a languor as if oppreſſed with a weight: this, therefore, muſt be accounted for from other cauſes than the diminution of that weight. M. de Sauſſure, when near the top of Mont Blanc, felt various ſymptoms of uneaſineſs, and was apparently ſeized with fever; but for theſe ſymptoms he accounts from another cauſe than the lightneſs of the atmoſphere. He obſerved that at that great height, *viz.* 2½ miles perpendicular from the ſea, the atmoſphere was ſo loaded with fixed air, that lime-water became quickly covered with a pellicle, occaſioned by the abſorption of fixed air. Now it is well known that fixed air produces ſymptoms ſimilar to thoſe deſcribed, on moſt animals. Mr. Derham's own experiments on the ſparrow prove, that no ſenſible effect was perceived from the compreſſion of the atmoſphere, to double its natural denſity; and perſons in the diving-bell are not ſenſible of any diſagreeable conſequence from the very great compreſſion of the air. EDITOR.

moſt animals live ſcarce half a minute (*f*); and others,

motion of the air, cauſed by their fluttering and ſhaking their wing (a thing worth trying in the *diving-bell).* I ſhall leave the ingenious reader to judge what the cauſe was of both the birds living longer in compreſſed, than uncompreſſed air; whether a leſs quantity of air was not ſooner fouled and rendered unfit for reſpiration, than a greater.

From theſe experiments two things are manifeſted; one is, that air, in ſome meaſure compreſſed, or rather heavy, is neceſſary to animal life: of which by and bye. The other, that freſh air is alſo neceſſary; for pent-up air, when overcharged with the vapours emitted out of the animal's body, becomes unfit for reſpiration. For which reaſon, in the *diving-bell*, after ſome time of ſtay under water, they are forced to come up and take in freſh air, or by ſome ſuch means recruit it. But the famous *Cornelius Drebell* contrived not only a veſſel to be rowed under water, but alſo a liquor to be carried in that veſſel, that would ſupply the want of freſh air. The veſſel was made for King *James* I. It carried twelve rowers, beſides the paſſengers. It was tried in the river of *Thames;* and one of the perſons that was in that ſubmarine navigation was then alive, and told it one, who related the matter to our famous founder, the honourable, and moſt ingenious Mr. *Boyle.* As to the liquor, Mr. *Boyle* ſaith, he diſcovered by a doctor of phyſic, who married *Drebell*'s daughter, that it was uſed from time to time when the air, in the ſubmarine boat, was clogged by the breath of the company, and thereby made unfit for reſpiration; at which time, by unſtopping a veſſel full of this liquor, he could ſpeedily reſtore to the troubled air ſuch a proportion of vital parts, as would make it again for a good while fit for reſpiration. The ſecret of this liquor *Drebell* would never diſcloſe to above one perſon, who himſelf aſſured Mr. *Boyle* what it was. *Vide* Boyle's *Exp. Phyſ. Mech. of the Spring of the Air*, *Exp.* 41. in the *Digreſſion.* This ſtory I have related from Mr. *Boyle*, but at the ſame time much queſtion whether the virtues of the liquor were ſo effectual as reported.

And

others, that are the moſt accuſtomed to the want of it, live not without it many days.

And

And as too groſs, ſo too rare an air is unfit for reſpiration. Not to mention the forced rarefactions made by the air-pump, in the following note; it is found, that even the extraordinary natural rarefactions, upon the tops of very high hills, much affect reſpiration. An eccleſiaſtical perſon, who had viſited the high mountains of *Armenia*, (on which ſome fancy the ark reſted,) told Mr. *Boyle*, that whilſt he was on the upper part of them, he was forced to fetch his breath oftener than he was wont: and taking notice of it when he came down, the people told him, that it was what happened to them when they were ſo high above the plain, and that it was a common obſervation among them. The like obſervation the ſame eccleſiaſtic made upon the top of a mountain in the *Cevennes*. So a learned traveller, and curious perſon, on one of the higheſt ridges of the *Pyrenees*, called *Pic de Midi*, found the air not ſo fit for reſpiration, as the common air, but he and his company were fain to breathe ſhorter and oftener than in the lower air. *Vide Phil. Tranſact.* No. 63. or *Lowthorp's Abridg.* vol. ii. p. 226.

Such another relation the learned *Joſeph Acoſta* gives of himſelf and his company, that, when they paſſed the high mountains of *Peru*, which they call *Periacaca*, (to which he ſaith, *the* Alps *themſelves ſeemed to them but as ordinary houſes, in regard of high towers,) he, and his companions, were ſurpriſed with ſuch extreme pangs of ſtraining and vomiting, (not without caſting up of blood too,) and with ſo violent a diſtemper, that he concludes he ſhould undoubtedly have died; but that this laſted not above three or four hours, before they came into a more convenient and natural temperature of the air.* All which, he concludes, proceeded from the too great ſubtilty and delicacy of the air, which is not proportionable to human reſpiration, which requires a more groſs and temperate air. *Vide* Boyle, *ubi ſupra.*

Thus it appears, that an air too ſubtile, rare, and light, is unfit for reſpiration: but the cauſe is not the ſubtilty, or too great delicacy, as Mr. *Boyle* thinks, but the too great lightneſs thereof, which renders it unable to be a counterbalance, or an antagoniſt

to

And not only animals themſelves, but even trees and plants, and the whole vegetable race, owe their

to the heart, and all the muſcles miniſtering to *reſpiration*; and the *diaſtole* of the heart. Of which ſee book iv. ch. 7. note 1.

And as our inability to live in too rare and light an air may diſcourage thoſe vain attempts of flying, and whimſies of paſſing to the moon, &c. ſo our being able to bear an heavier ſtate of the air is an excellent proviſion for men's occaſions in mines, and other great depths of the earth; and thoſe other greater preſſures made upon the air, in the *diving-bell*, when we deſcend into great depths of the waters.

(*d*) That the inhabitants of the air (birds and inſects) need the air as well as man, and other animals, is manifeſt from their ſpeedy dying in too feculent, or too much rarefied air; of which ſee the preceding and following note (*f*). But yet birds and inſects (ſome birds at leaſt) can live in a rarer air than man. Thus eagles, kites, herons, and divers other birds, that delight in high flights, are not affected with the rarity of the medium, as thoſe perſons were in the preceding note. So inſects bear the air-pump long, as in the following note (*f*).

(*e*) Creatures inhabiting the waters need the air, as well as other animals, yea, and freſh air too. The *hydrocanthari* of all ſorts, the *nymphæ* of *gnats*, and many other water inſects, have a ſingular faculty, and an admirable apparatus, to raiſe their back parts to the top of the waters, and take in freſh air. It is pretty to ſee, for inſtance, the *hydrocanthari* come and thruſt their tails out of the water, and take in a bubble of air, at the tip of their *vaginæ* and tails, and then nimbly carry it down with them into the waters; and when that is ſpent, or fouled, to aſcend again and recruit it.

So fiſhes alſo are well known to uſe reſpiration, by paſſing the water through their mouths and gills. But *carps* will live out of the water, only in the air: as is manifeſt by the experiment of their way of fatting them in *Holland*, and which hath been practiſed here in *England*, *viz.* they hang them up in a cellar, or ſome cool place, in wet moſs in a ſmall net, with their heads out, and feed them with white bread ſoaked in milk, for

their vegetation and life to this useful element; as will appear when I come to speak of them, and is manifest

for many days. This was told me by a person very curious, and of great honour and eminence, whose word (if I had leave to name him) nobody would question: and it being an instance of the respiration of fishes very singular, and somewhat out of the way, I have for the reader's diversion taken notice of it.

(*f*) By experiments I made myself in the air-pump, in *September* and *October* 1704, I observed that animals whose hearts have two *ventricles*, and no *foramen ovale*, as birds, dogs, cats, rats, mice, &c. die in less than half a minute counting from the very first exsuction; especially in a small receiver.

A *mole* (which I suspected might have borne more than other quadrupeds) died in one minute (without recovery) in a large receiver; and doubtless would hardly have survived half a minute in a small receiver. A *bat* (although wounded) sustained the pump two minutes, and revived upon the re-admission of the air. After that, he remained four minutes and a half, and revived. Lastly, after he had been five minutes, he continued gasping for a time, and after twenty minutes I re-admitted the air, but the *bat* never revived.

As for *insects*: *wasps*, *bees*, *hornets*, *grasshoppers*, and *lady-cows*, seemed dead in appearance in two minutes, but revived in the open air in two or three hours time, notwithstanding they had been in *vacuo* twenty-four hours.

The *ear-wig*, the great *staphylinus*, the great black lousy *beetle*, and some other insects, would seem unconcerned at the *vacuum* a good while, and lie as dead; but revive in the air, although some had lain sixteen hours in the exhausted receiver.

Snails bear the air-pump prodigiously, especially those in shells; two of which lay above twenty-four hours, and seemed not much affected. The same snails I left in twenty-eight hours more after a second exhaustion, and found one of them quite dead, but the other revived.

Frogs and *toads* bear the pump long, especially the former. A large toad, found in the house, died irrecoverable in less than six

manifeſt from their glory and verdure in a free air, and their becoming pale and ſickly, and languiſhing and dying, when by any means excluded from it (*g*).

Thus uſeful, thus neceſſary, is the air to the life of the animated creatures; and no leſs is it to the motion and conveyance of many of them. All the winged tribes owe their flight and bouyancy (*h*) to

ſix hours. Another toad and frog I put in together, and the toad was ſeemingly dead in two hours, but the frog juſt alive. After they had remained there eleven hours, and ſeemingly dead, the frog recovered in the open air, only weak, but the toad was quite dead. The ſame frog being put in again for twenty-ſeven hours, then quite died.

The animalcules in *pepper-water* remained in *vacuo* twenty-four hours. And after they had been expoſed a day or two to the open air, I found ſome of them dead, ſome alive.

(*g*) That the air is the principal cauſe of the vegetation of plants, *Borelli* proves, in his excellent book *De Mot. Animal.* vol. ii. prop. 181. And in the next propoſition, he aſſureth, *In plantis quoque peragi aeris reſpirationem quandam imperfectam, à quâ earum vita pendet, & conſervatur.*—" In plants there is likewiſe an imperfect reſpiration, on which their life and health depend."—But of this more when I come to ſurvey Vegetables.

Some lettice-ſeed being ſown upon ſome earth in the open air, and ſome of the ſame ſeed, at the ſame time, upon other earth in a glaſs-receiver of the pneumatic engine, afterwards exhauſted of air: the ſeed expoſed to the air, was grown up an inch and half high within eight days; but that in the exhauſted receiver not at all. And air being again admitted into the ſame emptied receiver, to ſee whether any of the ſeed would then come up, it was found, that in the ſpace of one week it was grown up to the height of two or three inches. Vide *Phil. Tranſ.* No. 23. *Lowth. Abridg.* vol. ii. p. 206.

(*h*) *In volucribus pulmones perforati aerem inſpiratum in totam ventris cavitatem admittunt. Hujus ratio, ut propter corporis truncum aere repletum & quaſi extenſum, ipſa magis volatilia evadant, faciliuſque*

to it, as ſhall be ſhewn in proper place: and even the watery inhabitants themſelves cannot aſcend and deſcend into their element, well without it (*i*).

But

faciliuſque ab aere externo, propter intimi penum, ſuſtententur. Equidem piſces, quò leviùs in aquis natent, in abdomine veſicas aere inflatas geſtant: pariter & volucres, propter corporis truncum aere impletum & quaſi inflatum, nudo aeri incumbentes, minus gravantur, proindeque leviùs & expeditiùs volant.—"In birds, the lungs being perforated, admit the inſpired air into the whole cavity of the belly. The purpoſe of this is, that their bodies being diſtended by the internal air, may be the more eaſily ſupported in flying. Fiſhes, for the ſame purpoſe, have inflated bladders of air in the cavity of the abdomen," &c.—*Willis de Anim. Brut.* p. 1. c. 3.—See *poſtea*, book vii. c. 2. note (*g*).

(*i*) *Fiſhes, by reaſon of the bladder of air within them, can ſuſtain, or keep themſelves in any depth of water: for the air in that bladder being more or leſs compreſſed, according to the depth the fiſh ſwims at, takes up more or leſs ſpace; and conſequently, the body of the fiſh, part of whoſe bulk this bladder is, is greater or leſs according to the ſeveral depths, and yet retains the ſame weight. Now the rule* de inſidentibus humido,—"*of things placed on water,*"—*is, That a body, that is heavier than ſo much water as is equal in quantity to the bulk of it, will ſink, a body that is lighter will ſwim; a body of equal weight will reſt in any part of the water. By this rule, if the fiſh, in the middle region of the water, be of equal weight to the water, that is, commenſurate to the bulk of it, the fiſh will reſt there, without any tendency upwards or downwards: and if the fiſh be deeper in the water, the bulk of the fiſh becoming leſs by the compreſſion of the bladder, and yet retaining the ſame weight, it will ſink, and reſt at the bottom. And on the other ſide, if the fiſh be higher than the middle region, the air dilating itſelf, and the bulk of the fiſh conſequently increaſing, but not the weight, the fiſh will riſe upwards and reſt at the top of the water. Perhaps, the fiſh by ſome action can emit air out of its bladder———, and, when not enough, take in air,———and then it will not be wondered, that there ſhould be always a fit proportion of air in all fiſhes to ſerve their uſe,* &c. Then follows a method of Mr. *Boyle*'s to experiment the truth of this. After which, in Mr. *Lowthorp*'s

Abridg-

But it would be tedious to defcend too far into particulars, to reckon up the many benefits of this noble appendage of our globe in many ufeful engines (*k*); in many of the functions and operations of nature (*l*) in the conveyance of founds; and

Abridgment, follow Mr. *Ray*'s obfervations. *I think that —— hath hit upon the true ufe of the fwimming bladders in fifhes.* For, 1. *It hath been obferved, that if the fwimming-bladder of any fifh be pricked or broken, fuch a fifh finks prefently to the bottom, and can neither fupport or raife itfelf up in the water.* 2. *Flat fifhes, as foles, plaife,* &c. *which lie always grovelling at the bottom, have no fwimming-bladders that ever I could find.* 3. *In moft fifhes there is a manifeft channel leading from the gullet——to the faid bladder, which, without doubt, ferves for the conveying air thereunto.—— In the coat of this bladder is a mufculous power to contract it when the fifh lifts.* See more very curious obfervations relating to this matter, of the late great Mr. *Ray*, as alfo of the curious anonymous Gentleman, in the ingenious Mr. *Lowthorp*'s Abridgment, before cited, p. 845. from *Philof. Tranf.* No. 114, 115.

(*k*) Among the engines in which the air is ufeful, pumps may be accounted not contemptible ones, and divers other hydraulical engines, which need not to be particularly infifted on. In thefe the water was imagined to rife by the power of fuction, to avoid a *vacuum*, and fuch unintelligible ftuff; but the juftly famous Mr. *Boyle* was the firft that folved thefe phænomena by the weight of the atmofphere. His ingenious and curious obfervations and experiments relating hereto, may be feen in his little tract, *Of the Caufe of Attraction by Suction*, and divers other of his tracts.

(*l*) It would be endlefs to fpecify the ufes of the air in nature's operations: I fhall therefore, for a fample only, name its great ufe to the world in conferving animated bodies, whether endowed with animal or vegetative life, and its contrary quality of diffolving other bodies; by which means many bodies that would prove nuifances to the world, are put out of the way, by being reduced into their firft principles, (as we fay,) and fo embodied with the earth again. Of its faculty as a menftruum, or

and a thoufand things befides. And I fhall but juft mention the admirable ufe of our atmofphere in miniftering to the enlightening of the world, by its reflecting the light of the heavenly bodies to us (*m*); and refracting the fun-beams to our eye, before

or its power to diffolve bodies; I may inftance in cryftal-glaffes, which, with long keeping, efpecially if not ufed, will in time be reduced to a powder, as I have feen. So divers minerals, earths, ftones, foffil-fhells, wood, *&c.* which from *Noah*'s flood, at leaft for many ages, have lain under ground, fo fecure from corruption, that, on the contrary, they have been thereby made much the ftronger, have in the open air foon mouldered away. Of which laft, Mr. *Boyle* gives an inftance (from the *Differtation de admirandis Hungar. Aquis)* of a great oak, like a huge beam, dug out of a falt-mine in *Tranfylvania*, *fo hard, that it would not eafily be wrought upon by iron tools, yet, being expofed to the air out of the mine, it became fo rotten that in four days it was eafy to be broken, and crumbled between one's fingers.* Boyle's Sufpic. about fome hidden Qualities in the Air, *p.* 28. So the trees turned out of the earth by the breaches at *Weft-Thurrock* and *Dagenham*, near me, although probably no other than *alder*, and interred many ages ago in a rotten oozy mould, were fo exceedingly tough, hard, and found at firft, that I could make but little impreffion on them with the ftrokes of an ax; but being expofed to the air and water, foon became fo rotten as to be crumbled between the fingers. See my Obfervations in *Philof. Tranfact.* No. 335.

(*m*) *By reflecting the light of the heavenly bodies to us*, I mean that whitenefs or lightnefs which is in the air in the day-time, caufed by the rays of light ftriking upon the particles of the atmofphere, as well as upon the clouds above, and the other objects beneath upon the earth. To the fame caufe alfo we owe the twilight, *viz.* to the fun-beams touching the uppermoft particles of our atmofphere, which they do when the fun is about eighteen degrees beneath the horizon. And as the beams reach more and more of the airy particles, fo darknefs goes off, and daylight

before it ever ſurmounteth our horizon (*n*); by which means the day is protracted throughout the

daylight comes on and increaſeth. For an exemplification of this, the experiment may ſerve of tranſmitting a few rays of the ſun through a ſmall hole into a dark room: by which means the rays which meet with duſt, and other particles flying in the air, are rendered viſible; or (which amounts to the ſame) thoſe ſwimming ſmall bodies are rendered viſible, by their reflecting the light of the ſun-beams to the eye, which, without ſuch reflection, would itſelf be inviſible.

The azure colour of the ſky Sir *Iſaac Newton* attributes to vapours beginning to condenſe, and that are not able to reflect the other colours. *V. Optic.* l. ii. par. 3. prop. 7.

(*n*) By the refractive power of the air, the ſun, and the other heavenly bodies ſeem higher than really they are, eſpecially near the horizon. What the refractions amount unto, what variations they have, and what alterations in time they cauſe, may be briefly ſeen in a little book called, *The Artificial Clock-Maker*, chap. 11. (written by Mr. Derham).

Although this inflective quality of the air be a great incumbrance and confuſion of aſtronomical obſervations;——yet it is not without ſome conſiderable benefit to navigation; and indeed, in ſome caſes, the benefit thereby obtained is much greater than would be the benefit of having the ray proceed in an exact ſtraight line. [Then he mentions the benefit hereof to the polar parts of the world.] *But this by the bye* (ſaith he). *The great advantage I conſider therein, is the firſt diſcovery of land upon the ſea; for by means hereof, the tops of hills and lands are raiſed up into the air, ſo as to be diſcoverable ſeveral leagues farther off on the ſea than they would be, were there no ſuch refraction, which is of great benefit to navigation for ſteering their courſe in the night, when they approach near land; and likewiſe for directing them in the day-time, much more certainly than the moſt exact celeſtial obſervations could do by the help of an uninflected ray, eſpecially in ſuch places as they have no ſoundings.* [Then he propoſes a method to find, by theſe means, the diſtance of objects at ſea.] *Vide Dr.* Hook's *Poſt. Works. Lect. of Navig.* p. 466.

whole

whole globe; and the long and diſmal nights are ſhortened in the frigid zones, and day ſooner approacheth them; yea, the ſun itſelf riſeth in appearance (when really it is abſent from them) to the great comfort of thoſe forlorn places (*o*).

But paſſing by all theſe things with only a bare mention, and wholly omitting others that might have been named, I ſhall only inſiſt upon the excellent uſe of this noble circumambient companion of our globe, in reſpect of two of its meteors, the winds, and the clouds and rain (*p*).

(*o*) *Cum Belgæ in Novâ Zemblâ hybernarent, ſol illis apparuit* 16 *diebus citiùs, quàm revera in horizonte exiſteret, hoc eſt, cùm adhuc infra horizontem depreſſus eſſet quatuor circiter gradibus, & quidem aere ſereno.*—" To thoſe Hollanders who wintered in Nova Zembla, the ſun was viſible, in a clear ſky, ſixteen days before it actually roſe above the horizon, being yet four degrees below it."—*Varen Geog.* c. 19. prop. 22.

[Theſe Hollanders] *found, that the night in that place ſhortened no leſs than a whole month; which muſt needs be a very great comfort to all ſuch places as live very far towards the north and ſouth poles, where length of night, and want of ſeeing the ſun, cannot chooſe but be very tedious and irkſome.* Hook, *ibid.*

[By means of the refractions] *we found the ſun to riſe twenty minutes before it ſhould; and in the evening to remain above the horizon twenty minutes (or thereabouts) longer than it ſhould.* Capt. *James's* Journ. in *Boyle* of Cold. Tit. 18. p. 190.

(*p*) *Aer—in nubes cogitur: humoremque colligens terram auget imbribus: tum effluens huc & illuc, ventos efficit. Idem annuas frigorum & calorum facit varietates: idemque & volatus alitum ſuſtinet; & ſpiritu ductus alit & ſuſtentat animantes.*—" The air, forming itſelf into clouds, and collecting moiſture from the earth, returns it again in ſhowers; or, being impelled in different directions, forms winds. To the air we owe the variations of heat and cold: the birds are ſupported by it in their flight; and all animals preſerved in life."—*Cic. de Nat. Deor.* l. ii. c. 39.

CHAP. II.

Of the Winds (a).

TO pafs by other confiderations, whereby I might demonftrate the winds to be the infinite Creator's contrivance, I fhall infift only upon their great ufefulnefs to the world. And fo great is

(*a*) *Ventus eft aer fluens*,—" Wind is air in motion,"—is *Seneca*'s definition. *Na. Qu.* l. v. And as wind is a current of the air, fo that which excites or alters its currents, may be juftly faid to be the caufe of the winds. An æquipoife of the atmofphere produceth a calm; but if that æquipoife be more or lefs taken off, a ftream of air, or wind, is thereby accordingly produced, either ftronger or weaker, fwifter or flower. And divers things there are that may make fuch alterations in the æquipoife or balance of the atmofphere, *viz.* eruptions of vapours from fea or land; rarefactions and condenfations in one place more than another; the falling of rain, preffure of the clouds, &c. *Pliny*, l. ii. c. 45. tells us of a certain *cavern* in *Dalmatia*, called *Senta*, *in quem*, faith he, *dejecto levi pondere, quamvis tranquillo die, turbini fimilis emicat procella*:—" a cavern, into which when any light body is thrown, although in a calm day, it produces a current of air like a whirlwind."—But as to caves it is obferved, that they often emit winds more or lefs. Dr. *Connor*, taking notice of this matter, fpecifies thefe, *In regno Neapolitano ex immani Cumanæ Sibyllæ antro tenuem ventum effluentem percepi.*—" From the fpacious grotto of the Cumæan Sibyl in the kingdom of Naples I perceived a fmall wind to iffue."—The like he obferved at the caves at *Baiæ*, and in fome of the mines of *Germany*, and in the large falt-mines of *Cracow* in *Poland*. *Ubi*, faith he, *opifices, & ipfe fodinæ dominus Andreas Morftin, nob. Polonus, mihi afferuerunt, quòd tanta aliquando ventorum*

is their uſe, and of ſuch abſolute neceſſity are they to the ſalubrity of the atmoſphere, that all the world would be poiſoned without thoſe agitations thereof. We find how putrid, fetid, and unfit for reſpiration,

torum tempeſtas ex ambagioſis hujus fodinæ receſſibus ſurgere ſolebat, quod laborantes foſſores humi proſternebat, nec non portas & domicilia (quæ ſibi in hâc fodinâ artifices exſtruunt) penitùs evertebat.— "Where the workmen and the maſter of the mines, a Poliſh nobleman, affirmed to me that a hurricane often iſſued from thoſe winding caverns ſo violent as to throw down the workmen, and demoliſh the houſes which they had built for their dwellings within the mines."—*Bern. Connor. Diſſert. Med. Phyſ.* p. 33. artic. 3.

And as great caves, ſo great lakes ſometimes ſend forth winds. So *Gaſſendus* ſaith the *Lacus Legnius* doth, *E quo dum exoritur fumus, nubes haud dubiè creanda eſt, quæ ſit brevi in tempeſtatem ſæviſſimam exoneranda.*—"From which a ſmoke ariſes which forms into a cloud, producing ſoon after a violent hurricane."—*Gaſſend. Vit. Peireſk.* l. v. p. 417.

But the moſt univerſal and conſtant alterations of the balance of the atmoſphere, are from heat and cold. This is manifeſt in the general trade-winds, blowing all the year between the tropics from eaſt to weſt: if the cauſe therefore be (as ſome ingenious men imagine) the ſun's daily progreſs round that part of the globe, and by his heat rarefying one part of the air, whilſt the cooler and heavier air behind preſſeth after. So the ſea and land-breezes in note (*d*). And ſo in our climate, the northerly and ſoutherly winds (commonly eſteemed the cauſes of cold and warm weather) are really the effects of the cold or warmth of the atmoſphere: of which I have had ſo many confirmations, that I have no doubt of it. As for inſtance, it is not uncommon to ſee a warm ſoutherly wind, ſuddenly changed to the north, by the fall of ſnow or hail; to ſee the wind in a froſty cold morning north, and when the ſun hath well warmed the earth and air, you may obſerve it to wheel about towards the ſoutherly quarters; and again to turn northerly or eaſterly in the cold evening. It is from hence alſo, that in thunder-

 ſhowers

refpiration, as weil as health and pleafure, a ftagnating, confined, pent-up air is. And if the whole mafs of air and vapours was always at reft, and without motion, inftead of refrefhing and animating, it would fuffocate and poifon all the world: but the perpetual commotions it receives from the gales and ftorms, keep it pure and healthful (*b*).

Neither

fhowers the wind and clouds are oftentimes contrary to one another, (efpecially if hail falls,) the fultry weather below directing the wind one way; and the cold above the clouds another way. I took notice upon *March* the 10th, 1710-11, (and divers fuch like inftances I have had before and fince,) that the morning was warm, and what wind ftirred was weft-fouth-weft, but the clouds were thick and black (as generally they are when fnow enfues): a little before noon the wind veered about to north by weft, and fometimes to other points, the clouds at the fame time flying fome north by weft, fome fouth-weft: about one of the clock it rained apace, the clouds flying fometimes north-eaft, then north, and at laft both wind and clouds fettled north by weft; at which time fleet fell plentifully, and it grew very cold. From all which I obferve, 1. That although our region below was warm, the region of the clouds was cold, as the black fnowy clouds fhewed. 2. That the ftruggle between the warmth of ours, and the cold of the cloudy region, ftopped the airy currents of both regions. 3. That the falling of the fnow through our warmer air melted into rain at firft; but that it became fleet after the fuperiour cold had conquered the inferiour warmth. 4. That, as that cold prevailed by degrees, fo by degrees it wheeled about both the winds and clouds from the northwards towards the fouth.

Hippocrates, l. ii. *De Vict. Orat. Omnes ventos vel à nive, glacie, vehementi gelu, fluminibus, &c. fpirare neceffe judicat.*—"He fuppofes that all winds arife either from fnow, ice, or froft, or from rivers," &c.—*Bartholin. de Ufu Nivis*, c. 1.

(*b*) *It is well obferved in my Lord* Howard's *Voyage to* Conftantinople, *That at* Vienna *they have frequent winds, which if they*

Neither are thofe ventilations beneficial only to the health, but to the pleafure alfo of the inhabitants of the terraqueous globe; witnefs the gales which fan us in the heat of fummer; without which, even in this our temperate zone, men are fcarce able to perform the labours of their calling, or not without danger of health and

they ceafe long in fummer, the plague often enfues: fo that it is now grown into a proverb, That if Auftria *be not windy, it is fubject to contagion.* Bohun of Wind, p. 213.

From fome fuch commotions of the air I imagine it is, that at *Grand-Cairo* the plague immediately ceafes, as foon as the *Nile* begins to overflow; although Mr. *Boyle* attributes it to nitrous corpufcles. *Determ. Nat. of Effluv.* c. 4.

Nulla enim propemodum regio eft, quæ non habeat aliquem flatum ex fe nafcentem, & circa fe cadentem.—" Almoft every region has a wind peculiar to itfelf."

Inter cætera itaq. Providentiæ opera, hoc quoq. aliquis, ut dignum admiratione fufpexerit. Non enim ex unâ caufâ ventos aut invenit, aut per diverfa difpofuit: fed primum ut aera non finerent pigrefcere, fed affiduâ vexatione utilem redderent, vitalemque tracturis.—" This is among the moft admirable of the works of Providence, that by means of the winds, the air is never fuffered to ftagnate, but always retains its vivifying quality."—*Sen. Nat. Quæft.* l. v. c. 17, 18.

All this is more evident, from the caufe affigned to malignant epidemical difeafes, particularly the plague, by my ingenious learned friend Dr. *Mead;* and that is, an hot and moift temperament of the air, which is obferved by *Hippocrates*, *Galen*, and the general hiftories of epidemical difeafes, to attend thofe diftempers. *Vide* Mead *of Poifons*, Effay v. p. 161. But indeed, whether the caufe be this, or poifonous malignant exhalations or animalcules, as others think, the winds are, however, very falutiferous in fuch cafes, in cooling the air, and difperfing and driving away the moift or peftiferous vapours.

 life.

life (*c*). But eſpecially, witneſs the perpetual gales which throughout the whole year do fan the torrid zone,

(*c*) *July* 8, 1707, (called for ſome time after the *Hot Tueſday*,) was ſo exceſſively hot and ſuffocating, by reaſon there was no wind ſtirring, that divers perſons died, or were in great danger of death, in their harveſt-work; particularly one who had formerly been my ſervant, a healthy, luſty, young man, was killed by the heat; and ſeveral horſes on the road dropped down and died the ſame day.

In the foregoing notes, having notice of ſome things relating to heat, although it be ſomewhat out of the way, I hope the reader will excuſe me, if I entertain him with ſome obſervations I made about the heat of the air under the line, compared with the heat of our bodies. *J. Patrick*, who, as he is very accurate in making barometrical and thermometrical inſtruments, had the curioſity, for the nicer adjuſting his thermometers, to ſend two abroad under the care of two very ſenſible ingenious men; one to the northern lat. of 81; the other to the parts under the æquinoctial: in theſe two different climates, the places were marked where the ſpirits ſtood at the ſevereſt cold and greateſt heat. And according to theſe obſervations he graduates his thermometers. With his ſtandard I compared my ſtandard thermometer, from all the degrees of cold I could make with *ſal ammoniack*, &c. to the greateſt degrees of heat our thermometers would reach to. And with the ſame thermometer (of mine) I experimented the greateſt heat of my body, in *July* 1709: firſt in an hot day without exerciſe, by putting the ball of my thermometer under my armpits, and other hotteſt parts of my body; by which means the ſpirits were raiſed 284 tenths of an inch above the ball. After that, in a much hotter day, and indeed nearly as hot as any day with us, and after I had heated myſelf with ſtrong exerciſe too, as much as I could well bear, I again tried the ſame experiment, but could not get the ſpirits above 288 tenths; which I thought an inconſiderable difference, for ſo ſeemingly a very different heat of my body. But from ſome experiments I have made (although I have

zone, and make that climate an healthful and pleasant habitation, which would otherwise be scarce habitable.

To these I might add many other great conveniencies of the winds in various engines, and various businesses. I might particularly insist upon its great use to transport men to the farthest distant regions of the world (*d*); and I might particularly speak

have unfortunately forgotten them) in very cold weather, I imagine the heat of an healthy body to be always much the same, in the warmest parts thereof, both in summer and winter. Now between those very degrees of 284 and 288, the point of the equatorial heat falleth. From which observation it appears, that there is pretty nearly an equal contemperament of the warmth of our bodies, to that of the hottest part of the atmosphere inhabited by us.

If the proportion of the degrees of heat be desired from the freezing-point, to the winter, spring, and summer air, the heat of man's body, of heated water, melted metals, and so to actual fire; an account may be met with of it, by my most ingenious friend the great Sir *Isaac Newton*, in *Phil. Transact.* No. 270.

(*d*) *In hoc* Providentia *ac* Dispositor *ille mundi* Deus, *aera ventis exercendum dedit,——non ut nos classes partem freti occupaturas compleremus milite armato, &c. Dedit ille ventos ad custodiendam cœli terrarumq. temperiem, ad evocandas supprimendásq. aquas, ad alendos satorum atque arborum fructus; quos ad maturitatem cum aliis causis adducit ipsa jactatio, attrahens cibum in summa, & ne torpeat, promovens. Dedit ventos ad ulteriora noscenda: fuisset enim imperitum animal, & sine magnâ experientiâ rerum homo, si circumscriberetur natalis soli fine. Dedit ventos ut commoda cujusque regionis fierent communia; non ut legiones equitemque gestarent, nec ut perniciosa gentibus arma transveherent.*— "That Almighty Providence, that God who has formed every thing for the wisest ends, has provided that the air shall be kept in

ſpeak of the general and coaſting trade-winds, the ſea and the land breezes (*e*); the one ſerving to carry the mariner in long voyages from eaſt to weſt; the other ſerving to waft him to particular places; the one ſerving to carry him into his harbour, the other to bring him out. But I ſhould go

in continual motion by the winds: not for this purpoſe, that man ſhould cover the face of the deep with hoſtile armaments. He gave the winds in order to preſerve the temperature of the earth and air; to drain off ſuperfluous moiſture; to invigorate the fructiferous herbs and trees, which even agitation, amidſt other cauſes, conduces to bring to maturity, by drawing upwards the nutritive juices, and preventing their ſtagnation. He gave the winds, that man, by navigation, might increaſe his knowledge, and extend that experience which otherwiſe would be confined to his native ſoil. He gave the winds, that men might enjoy in common the productions of every climate: not that they might tranſport armies for the deſtruction of each other, and the ruin of the human race."—*Seneca, Nat. Quæſt.* l. v. c. 18.

(*e*) Sea-breezes *commonly riſe in the morning about nine o'clock.*——*They firſt approach the ſhore gently, as if they were afraid to come near it.*——*It comes in a fine, ſmall, black curl upon the water, whereas all the ſea between it and the ſhore (not yet reached by it) is as ſmooth and even as glaſs in compariſon. In half an hour's time after it has reached the ſhore, it fans pretty briſkly, and ſo increaſeth gradually till twelve o'clock; then it is commonly the ſtrongeſt, and laſts ſo till two or three, a very briſk gale.*——*After three it begins to die away again, and gradually withdraws its force till all is ſpent; and about five o'clock it is lulled aſleep, and comes no more till next morning.*

And as the ſea-breezes do blow in the day, and reſt in the night; ſo on the contrary, the land-breezes *blow in the night, and reſt in the day, alternately ſucceeding each other. They ſpring up between ſix and twelve at night, and laſt till ſix, eight, or ten in the morning.* Dampier's Diſc. of Winds, *c.* 4.

too far to take notice of all particulars (*f*). Leaving therefore the winds, I proceed, in the next place, to the clouds and rain.

(*f*) One thing more I believe ſome of my friends will expect from me is, that I ſhew the reſult of comparing my own obſervations of the winds, with others they know I have from *Ireland*, *Switzerland*, *Italy*, *France*, *New-England*, and ſome of our parts of *England*. But the obſervations being, ſome of them, but of one year, and moſt of the reſt of but a few years, I have not been able to determine any great matters. The chief of what I have obſerved is, that the winds in all theſe places ſeldom agree; but when they moſt certainly do ſo, it is commonly when the winds are ſtrong, and of long continuance in the ſame quarter: and more, I think, in the northerly and eaſterly, than other points. Alſo, a ſtrong wind in one place, is oftentimes a weak one in another place, or moderate, according as places have been nearer or farther diſtant. Vide *Philoſ. Tranſact.* No. 297 and 321. But to give a good and tolerable account of this, or any other of the weather, it is neceſſary to have good hiſtories thereof from all parts; which as yet we have but few of, and they imperfect, for want of longer and ſufficient obſervations.

CHAP. III.

Of the Clouds and Rain.

THE Clouds and Rain (*a*) we ſhall find to be no leſs uſeful meteors than the laſt mentioned; as is manifeſt in the refreſhing pleaſant ſhades which the clouds afford, and the fertile dews and ſhowers which

(*a*) Clouds and rain are made of vapours raiſed from water, or moiſture only. So that I utterly exclude the notion of dry, terrene exhalations, or fumes, talked much of by moſt philoſophers; fumes being really no other than the humid parts of bodies reſpectively dry.

Theſe vapours are demonſtratively no other than ſmall bubbles, or veſiculæ detached from the waters by the power of the ſolar, or ſubterraneous heat, or both. Of which ſee *Book* ii. *chap.* v. *note* (*b*). And being lighter than the atmoſphere, are buoyed up thereby, until they become of an equal weight therewith, in ſome of its regions aloft in the air, or nearer the earth; in which thoſe vapours are formed into clouds, rain, ſnow, hail, lightning, dew, miſts, and other meteors.

In this formation of meteors the grand agent is cold, which commonly, if not always, occupies the ſuperior regions of the air; as is manifeſt from thoſe mountains which exalt their lofty tops into the upper and middle regions, and are always covered with ſnow and ice.

This cold, if it approaches near the earth, preſently precipitates the vapours, either in *dews*; or, if the vapours more copiouſly aſcend, and ſoon meet the cold, they are then condenſed into *miſling*, or elſe into ſhowers of *ſmall rain*, falling in numerous, thick, ſmall drops: but if thoſe vapours are not only copious, but alſo as heavy as our lower air itſelf, (by reaſon that their bladders

which they pour down on the trees and plants, which would languiſh and die with perpetual drought,

bladders are thick and fuller of water,) in this caſe they become viſible, ſwim but a little height above the earth, and make what we call a *miſt* or *fog*. But if they are a degree lighter, ſo as to mount higher, but not any great height, as alſo meet not with cold enough to condenſe them, nor wind to diſſipate them, they then form an heavy, thick, *dark ſky*, laſting oftentimes for ſeveral weeks without either ſun or rain. And in this caſe, I have ſcarce ever known it to rain, till it hath been *firſt fair, and then foul.* And Mr. *Clarke*, (an ingenious clergyman of *Norfolk*,) who in his lifetime, long before me, took notice of it, and kept a regiſter of the weather for thirty years, which his learned grandſon Dr. *Samuel Clarke* put into my hands, he (I ſay) ſaith, he ſcarce ever obſerved the rule to fail in all that time; only he adds, *If the wind be in ſome of the eaſterly points.* But I have obſerved the ſame to happen, be the wind where it will. And from what hath been ſaid, the caſe is eaſily accounted for, *viz.* whilſt the vapours remain in the ſame ſtate, the weather doth ſo too. And ſuch weather is generally attended with moderate warmth, and with little or no wind to diſturb the vapours, and an heavy atmoſphere to ſupport them, the barometer being commonly high then. But when the cold approacheth, and by condenſing drives the vapours into clouds or drops, then is way made for the ſun-beams, till the ſame vapours, being by further condenſation formed into rain, fall down in drops.

The cold's approaching the vapours, and conſequently the alteration of ſuch dark weather I have beforehand perceived, by ſome few ſmall drops of rain, hail, or ſnow, now and then falling, before any alteration hath been in the weather; which I take to be from the cold meeting ſome of the ſtraggling vapours, or the uppermoſt of them, and condenſing them into drops, before it arrives unto, and exerts itſelf upon the main body of vapours below.

I have more largely than ordinary inſiſted upon this part of the weather, partly as being ſomewhat out of the way; but chiefly, becauſe

drought, but are hereby made verdant and flouriſhing, gay and ornamental; ſo that (as the Pſalmiſt ſaith,

becauſe it gives light to many other *phenomena* of the weather. Particularly we may hence diſcover the original of clouds, rain, hail, and ſnow; that they are vapours carried aloft by the gravity of the air, which meeting together ſo as to make a fog above, they thereby form a *cloud*. If the cold condenſeth them into drops, they then fall in *rain*, if the cold be not intenſe enough to freeze them: but if the cold freezeth them in the clouds, or in their fall through the air, they then become *hail* or *ſnow*.

As to *lightning*, and other enkindled vapours, I need ſay little in this place, and ſhall therefore only obſerve, that they owe alſo their riſe to vapours; but ſuch vapours as are detached from mineral juices, or at leaſt that are mingled with them, and are fired by fermentation *.

Another

* At the time when our author wrote, electricity, which now forms ſo conſiderable a part of natural ſcience, was known only in the trifling phenomena exhibited by amber, roſin, and vitrous ſubſtances, attracting minute particles of matter when rubbed. It was not till 1745 that the method of collecting the electrical fluid by means of the Leyden phial was diſcovered; and it was ſo late as 1750, that Dr. Franklin, from ſome hints of the Abbé Nollet, Mr. Winkler, and others, of the reſemblance between the phenomena of electricity and thoſe of thunder, aſcertained the fact of their identity, by producing all the electrical phenomena from lightning drawn from the clouds by a pointed rod, or armed paper kite. Since that time an infinite number of experiments have ſhewn that the electric fluid is diffuſed through all Nature, and is an active agent in moſt of her operations. The formation of clouds and their motion; thunder and lightning; the aurora borealis; earthquakes, volcanoes; and in many caſes, probably, the phenomena of rain, hail, and ſnow, in a great degree, depend on the operation of this all-pervading fluid. I ſhall, therefore, be eaſily excuſed for reſuming the

ſaith, *Pſal.* lxv. 12, 13.) *The little hills rejoice on every ſide, and the valleys ſhout for joy, they alſo ſing.* And

Another *phenomenon* reſolvable from what hath been ſaid is, why a *cold*, is always a *wet* ſummer, *viz.* becauſe the vapours riſing plentifully then, are by the cold ſoon collected into rain. A remarkable inſtance of this we had in the ſummer of 1708, part of which, eſpecially about the ſolſtice, was much colder than uſual. On *June* 12, it was ſo cold, that my thermometer was near the point of hoar froſt, and in ſome places I heard there was an hoar froſt; and during all the cool weather of that month, we had frequent and large rains, ſo that the whole month's rain amounted to above two inches dépth, which is a large quantity for *Upminſter*, even in the wetteſt months. And not only with us at *Upminſter*, but in other places, particularly at *Zurich* in *Switzerland*, they ſeem to have had as unſeaſonable cold and wet as we.—*Fuit hic menſis, præter modum humidus, & magno quidem vegetabilibus hominibuſque damno. Multum computruit fœnum*, &c.— "This month was beyond meaſure watery, and extremely dè-trimental to vegetables, and hurtful to the human ſpecies. The hay became rotten," &c.—complains the induſtrious and learned Dr. *J. J. Scheuchzer*: of which, and other particulars, I have given a larger account in *Phil. Tranſ.* No. 321.

In which *Tranſaction* I have obſerved farther, that about the equinoxes we (at *Upminſter* at leaſt) have oftentimes more rain than at other ſeaſons. The reaſon of which is manifeſt from what hath been ſaid, *viz.* in ſpring, when the earth and waters are looſed from the brumal conſtipations, the vapours ariſe in great plenty: and the like they do in autumn, when the ſummer heats, that both diſſipated them, and warmed the ſuperior regions, are abated; and then the cold of the ſuperior regions meeting them, condenſeth them into ſhowers, more plentifully than at other

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the conſideration of this ſubject in a note at the concluſion of this firſt Book, in which I ſhall endeavour briefly to enumerate the various uſes and operations of the electrical fluid in the ſyſtem of nature at large. EDITOR.

And if to theſe uſes, we ſhould add the origin of fountains and rivers, to vapours and the rains, as ſome

other ſeaſons, when either the vapours are fewer, or the cold that is to condenſe them is leſs.

The manner how vapours are precipitated by the cold, or reduced into drops, I conceive to be thus: vapours being, as I ſaid, no other than inflated *veſiculæ* of water; when they meet with a colder air than what is contained in them, the contained air is reduced into a leſs ſpace, and the watery ſhell or caſe rendered thicker by that means, ſo as to become heavier than the air, by which they are buoyed up, and conſequently they muſt needs fall down. Alſo many of thoſe thickened *veſiculæ* run into one, and ſo form drops, greater or ſmaller, according to the quantity of vapours collected together.

As to the rain of different places, I have in ſome of our *Tranſactions* aſſigned the quantities; particularly in the laſt cited *Tranſaction*, I have aſſigned theſe, *viz.* the depth of the rain one year with another, in *Engliſh* meaſure, if it was to ſtagnate on the earth, would amount unto, at *Towndy* in *Lancaſhire*, 42 inches and a half; at *Upminſter* in *Eſſex* 19 inches and a quarter; at *Zurich* in *Switzerland* 32 inches and a quarter; at *Piſa* in *Italy* 43 inches and a quarter; at *Paris* in *France* 19 inches; and at *Liſle* in *Flanders* 24 inches.

It would be endleſs to reckon up the *bloody* and other *prodigious rains* taken notice of by hiſtorians, and other authors, as præternatural and ominous accidents; but which, if ſtrictly pried into, will be found owing to natural cauſes: of which, for the reader's ſatisfaction, I will give an inſtance or two. A bloody rain was imagined to have fallen in *France*, which put the country people into ſo great a fright, that they left their work in the fields, and in great haſte flew to the neighbouring houſes. *Peireſc* (then in the neighbourhood) ſtrictly inquiring into the cauſe, found it to be only red drops coming from a ſort of butterfly that flew about in great numbers at that time, as he concluded from ſeeing ſuch red drops come from them; and becauſe theſe drops were laid, *Non ſupra ædificia, non in devexis lapidum ſuperficiebus, uti debuerat contingere,*

ſome of the moſt eminent modern philoſophers (*b*) have done, we ſhould have another inſtance of the great uſe and benefit of that meteor.

And

contingere, ſi è cœlo ſanguine pluiſſet; ſed in ſubcavis potius & in foraminibus.—Acceſſit, quòd parietes iis tingebantur, non qui in mediis oppidis, ſed qui agrorum vicini erant, neque ſecundùm partes elatiores, ſed ad mediocrem ſolùm altitudinem, quantam volitare papiliones ſolent.—" Not upon the houſe-tops, nor on the hollow ſurfaces of ſtones, as muſt have happened if the bloody ſhower had fallen from the atmoſphere; but on the contrary, in covered holes and cavities. It happened, moreover, that ſuch walls only were ſtained with theſe drops as were adjoining to the fields, not ſuch as were in the midſt of towns; and thoſe were not tinged in the higher parts, but only to a moderate height; ſo high as the butterflies are wont to fly."—*Gaſſend. in Vit. Peireſk*, l. 2. p. 156.

So Dr. *Merret* ſaith alſo, *Pluvia ſanguinis quàm certiſſime conſtat eſſe tantùm inſectorum excrementa; pluvia tritici nihil aliud eſſe quàm hederæ bacciferæ grana à ſturnis devorata excretaque comparanti quàm liquidiſſimè patet.*—" It is known for certain that thoſe bloody ſhowers are nothing elſe than the excrements of inſects: and it is evident, upon comparing them together, that the ſhowers of wheat are only the ſeeds of the berry-bearing ivy, after they have been devoured by the ſtarlings and evacuated."—*Pinax Rerum*, &c. p. 220.

The curious *Worm* tells of the raining of brimſtone, *an.* 1646, *Maii* 16. *Hìc Hafniæ cùm ingenti pluviâ tota urbs, omneſque ita inundarentur plateæ, ut greſſus hominum impediret. ſulphureoque odore aërem inficeret, dilapſis aliquantulum aquis, quibuſdam in locis colligere licuit ſulphureum pulverem, cujus portionem ſervo, colore, odore, & aliis verum ſulphur ferentem* —" Here, at Copenhagen, when the whole town was overflowed by a great fall of rain, ſo that the ſtreets became impaſſable, the air was infected with a ſulphureous ſmell; and when the waters were a little ſubſided, one might have collected in ſome places a ſulphureous powder, of which I have preſerved a part; and which in colour, ſmell, and

every

And now, if we reflect upon this neceffary appendage of the terraqueous globe, the *atmofphere*; and

every other quality appeared to be real fulphur."—*Muf. Worm.* l. 1. c. 11. fect. 1.

Together with the rain we might take notice of other meteors, particularly *fnow*; which although an irkfome gueft, yet hath its great ufes, if all be true that the famous *T. Bartholin* faith of it, who wrote a book *de Nivis Ufu Medico.* In which he fhews of what great ufe fnow is in fructifying the earth, preferving from the plague, curing fevers, colics, headaches, toothaches, fore eyes, pleurifies, (for which ufe he faith his countrywomen of *Denmark* keep fnow-water gathered in *March*,) alfo in prolonging life (of which he inftanceth in the *Alpine* inhabitants, that live to a great age) and preferving dead bodies; inftances of which he gives in perfons buried under the fnow in paffing the *Alps*, which are found uncorrupted in the fummer, when the fnow is melted; which fad fpectacle he himfelf was an eye-witnefs of. And at *Spitzberg* in *Greenland*, dead bodies remain entire and uncorrupted for thirty years. And laftly, concerning fuch as are fo preferved when flain, he faith they remain in the fame pofture and figure: of which he gives this odd example. *Vifum id extra urbem noftram* [Hafniam] *quum*, 11 *Feb.* 1659, *oppugnantes hoftes repellerentur, magnâque ftrage occumberent; alii enim rigidi iratum vultum oftendebant, alii oculcs elatos; alii ore diducto ringentes, alii brachiis extenfis gladium minari, alii alio fitu proftrati jacebant.*—"That was feen without the walls of our city (Copenhagen), when, on the 11th February 1659, the befiegers were repulfed and cut to pieces with great flaughter. Some of the ftiffened bodies of the dead exhibited ftill an angry countenance; fome had their eyes lifted up; fome grinned with their extended mouths; others with outftretched arms brandifhed their fwords; fome, in fhort, lay in one pofture, and fome in another."—*Barthol. de Ufu Niv.* c. 12.

But although fnow be attended with the effects here named, and others fpecified by the learned Bartholin; yet this is not to be attributed to any peculiar virtue in the fnow, but fome other caufe.

and conſider the abſolute neceſſity thereof to many uſes of our globe; and its great convenience to the whole;

cauſe. Thus when it is ſaid to *fructify the earth*, it doth ſo by guarding the corn or other vegetables againſt the intenſer cold of the air, eſpecially the cold piercing winds; which the huſbandmen obſerve to be the moſt injurious to their corn of all weathers. So for *conſerving dead bodies*, it doth it by conſtipating ſuch bodies, and preventing all ſuch fermentations or internal conflicts of their particles, as would produce corruption.

Such an example as the preceding is ſaid to have happened ſome years ago at *Paris*, in digging in a cellar for ſuppoſed hidden treaſure; in which, after digging ſome hours, the maid going to call her maſter, found them all in their digging poſtures, but dead. This being noiſed abroad, brought in not only the people, but magiſtrates alſo, who found them accordingly; *Ille qui ligone terram effoderat, & ſocius qui palâ effoſſam terram removerat, ambo pedibus ſtabant, quaſi ſuo quiſque operi affixus incubuiſſet; uxor unius quaſi ab opere defeſſa in ſcamno, ſolicito quodam vultu, ſedebat, inclinato in palmam manûs genibus innitentis capite; puerulus laxatis braccis in margine excavatæ foveæ defixis in terram oculis alvum exonerabat; omnes in naturali ſitu, carneæ tanquam ſtatuæ rigidi, apertis oculis & vultu vitam quaſi reſpirante, exanimes ſtabant.*— "He that was digging the earth with a ſpade, and his comrade who was removing it with a ſhovel, both ſtood on their feet, as if intent upon their work. The wife of one of them, to appearance tired with working, was ſitting on a bench with an anxious countenance, leaning her head againſt the palm of her hand, her arm reſting on her knees; a little boy with his breeches down, ſat in a corner of the cellar eaſing himſelf, his eyes fixed on the ground: all remained in their natural poſture, dead and ſtiff, like ſo many ſtatues of fleſh, with their eyes open, and with the faces of people apparently alive."—*Dr. Bern. Connor, Diſſert. Med. Phyſ.* p. 15,

The doctor attributes all this to cold; but I ſcarce think there could be cold enough to do all this at *Paris*, and in a cellar too. But his following ſtories are not improbable, of men and cattle

killed

whole; and in a word, that it anſwereth all the ends and purpoſes that we can ſuppoſe there can be for ſuch an appendage: who can but own this to be the contrivance, the work of the great Creator? Who would ever ſay or imagine ſuch a body, ſo different from the globe it ſerves, could be made by chance, or be adapted ſo exactly to all thoſe forementioned grand ends, by any other efficient than by the power and wiſdom of the infinite God! Who would not rather, from ſo noble a work, readily acknowledge the workman (*c*), and as eaſily conclude

killed with cold, that remained in the very ſame poſture in which they died; of which he gives, from a *Spaniſh* captain, this inſtance, that happened two years before, of a ſoldier who unfortunately ſtraggled from his company that were foraging, and was killed with the cold, but was thought to have fallen into the enemy's hands. But ſoon after their return to their quarters, they ſaw their comrade returning, ſitting on horſeback, and coming to congratulate him, found him dead, and that he had been brought thither in the ſame poſture on horſeback, notwithſtanding the jolting of the horſe. *Ibid.* p. 18.

(*b*) Of this opinion was my late moſt ingenious and learned friend, Mr. *Ray*, whoſe reaſons ſee in his *Phyſico-Theolog. Diſcourſes*, Diſc. 2. c. 2. p. 89, *&c.* So alſo my no leſs learned and ingenious friends, Dr. *Halley* and the late Dr. *Hook*, many of the *French* virtuoſo's alſo, and divers other very conſiderable men before them, too many to be ſpecified here.

(*c*) *An Polycletum quidem admirabimur propter partium ſtatuæ—convenientiam ac proportionem? Naturam autem non modò non laudabimus, ſed omni etiam arte privabimus, quæ partium proportionem non ſolùm extrinſecus more ſtatuariorum, ſed in profundo etiam ſervavit? Nonne & Polycletus ipſe Naturæ eſt imitator, in quibus ſaltem eam potuit imitari? Potuit autem in ſolis externis partibus in quibus artem conſideravit.* With much more to the like purpoſe "Shall we

conclude the atmofphere to be made by God, as an inftrument wrought by its power, any pneumatic engine, to be contrived and made by man!

we admire the art of Polycletus for the excellent proportions and aptitude of the parts in his ftatues? And fhall we not only refufe our admiration, but even deny all art or contrivance to Nature, who in her works, hath not only preferved with the fkill of a ftatuary the external proportions, but fafhioned them likewife fo exquifitely within? Is not Polycletus himfelf but an imitator of Nature, and in thofe points alone, in which fhe can be imitated? for he could imitate her only in thofe external parts, in which her ingenuity was open to view."—*Galen de Uf. Part. l.* 17. *c.* 1.

CHAP. IV.

Of Light.

THUS much for the firſt thing miniſtering to the terraqueous globe, the atmoſphere and its meteors; the next appendage is *light* (*a*). Concerning which, I have in my ſurvey of the heavens (*b*) ſhewed what admirable contrivances the infinitely wiſe Creator hath for the affording this noble, glorious, and comfortable benefit to other globes, as well as ours; the proviſion he hath made by moons, as well as by the ſun, for the communication of it.

(*a*) It is not worth while to enumerate the opinions of the *Ariſtotelians*, *Carteſians*, and others, about the nature of light, *Ariſtotle* making it a quality; *Cartes* a pulſion, or motion of the globules of the ſecond element. Vide *Cartes Princip.* p. 3. ſect. 55, &c. But with the moderns, I take *light* to conſiſt of material particles, propagated from the ſun, and other luminous bodies, not inſtantaneouſly, but in time, according to the notes following in this chapter. But not to inſiſt upon other arguments for the proof of it, our noble founder hath proved the materiality of light and heat, from actual experiments on ſilver, copper, tin, lead, ſpelter, iron, tutenage, and other bodies, expoſed (both naked and cloſely ſhut up) to the fire: all which were conſtantly found to receive an increment of weight. I wiſh he could have met with a ſavourable ſeaſon to have tried his experiments with the ſun-beams as he intended. *Vide* Boyle's *Exp. to make Fire and Flame ponderable.*

(*b*) *Aſtro-Theol.* b. 7.

And now let us briefly confider the great neceffity and ufe thereof to all our animal world. And this we fhall find to be little lefs than the very life and pleafure of all thofe creatures. For what benefit would life be of, what pleafure, what comfort would it be for us to live in perpetual darknefs? How could we provide ourfelves with food and neceffaries? How could we go about the leaft bufinefs, correfpond with one another, or be of any ufe in the world, or any creatures be the fame to us, without light, and thofe admirable organs of the body, which the great *Creator* hath adapted to the perception of that great benefit?

But now by the help of this admirable, this firft-made (*c*), becaufe moft neceffary, creature of God; by this, I fay, all the animal world is enabled to go here and there, as their occafions call; they can tranfact their bufinefs by day, and refrefh and recruit themfelves by night with reft and fleep. They can with admiration and pleafure behold the glorious works of God; they can view the glories of the heavens, and fee the beauties of the flowery fields, the gay attire of the feathered tribe, the exquifite garniture of many quadrupeds, infects, and other creatures; they can take in the delightfome landfcapes of divers countries and places; they can with admiration fee the great Creator's wonderful art and contrivance in the parts of animals and ve-

(*c*) *And God faid, Let there be light, and there was light.* Gen. i. 3.

getables: and, in a word, behold the harmony of this lower world, and of the globes above, and furvey God's exquifite workmanfhip in every creature *.

To all which I might add the improvements which the fagacity of men hath made of this noble creature of God, by the refractions and reflections of glaffes. But it would be endlefs to enumerate all its particular ufes and benefits to our world.

But before I leave this point, there are two things concerning light, which will deferve an efpecial remark; and that is, its fwift and almoft inftantaneous motion, and its vaft extenfion.

1. It is a very great act of the providence of God, that fo great a benefit as light is, is not long in its paffage from place to place. For was the motion thereof no fwifter than the motion of the fwifteft bodies on earth, fuch as of a bullet out of a great gun, or even of a found (*d*), (which is the fwifteft motion

(*d*) It may not be ungrateful to the curious, to take notice of the velocity of thefe two things.

According to the obfervations of *Merfennus*, a bullet-fhot out of a great gun, flies 92 fathom in a fecond of time, (vide *Merfen. Balift.*)

* The green colour of plants depends entirely on the fun's light being allowed to fhine upon them, for when growing in a dark place they are perfectly white. An experiment has likewife been tried whether a conftant and ftrong light from a great number of lamps, kept continually burning, might not have the fame effect as the day-light, but the plants remained quite colourlefs as thofe growing in the dark. EDITOR.

motion we have next light,) in this caſe light would take up, in its progreſs from the ſun to us, above thirty-two years, at the rate of the firſt; and above ſeventeen years, at the rate of the latter motion.

The inconveniencies of which would be, its energy and vigour would be greatly cooled and abated; its rays would be leſs penetrant; and darkneſs would with greater difficulty and much ſluggiſhneſs be diſſipated, eſpecially by the fainter lights of our ſublunary luminous bodies. But paſſing with ſuch prodigious velocity, with nearly the inſtantaneous ſwiftneſs of almoſt two hundred thouſand *Engliſh* miles in one ſecond of time (*e*), or (which

Baliſt.) which is equal to 589 *Engliſh* feet and a half, and according to the computation of Mr. *Huygens*, it would be 25 years in paſſing from the earth to the ſun. But according to my own obſervations made with one of her late Majeſty's *ſakers*, and a very accurate pendulum-chronometer, a bullet, at its firſt diſcharge, flies 510 yards in five half ſeconds, which is a mile in a little above 17 half ſeconds. And allowing the ſun's diſtance to be, as in the next note, a bullet would be 32 years and a half in flying, with its utmoſt velocity, to the ſun.

As to the velocity of ſound, ſee *book* 4. *chap.* 3. *note* 28, according to which rate there mentioned, a ſound would be near 17 years and a half in flying as far as the diſtance is from the earth to the ſun. Confer here the experiments of the *Acad. del Ciment.* p. 140, *&c.*

(*e*) Mr. *Romer*'s ingenious hypotheſis about the velocity of light, hath been eſtabliſhed by the *Royal Academy*, and in the *Obſervatory* for eight years, as our *Phil. Tranſ.* No. 136, obſerve from the *Journ. des Scavans*; our moſt eminent aſtronomers

(which is the ſame thing) being but about ſeven or eight minutes of an hour in coming from the ſun to us, therefore with all ſecurity and ſpeed, we receive the kindly effects and influences of that noble and uſeful creature of God.

2. Another thing of great conſideration about light is, its vaſt expanſion, its almoſt incomprehenſible and inconceivable extenſion, which, as a late ingenious author (*f*) ſaith, "Is as boundleſs "and unlimited as the univerſe itſelf, or the ex-"panſum of all material beings: the vaſtneſs of "which is ſo great, that it exceeds the comprehen-

mers alſo in *England* admit it: but Dr. *Hook* thinks with Monſieur *Cartes*, the motion of light inſtantaneous, *Hook's Poſt. Works*, p. 77. And this he endeavours to explain, *p.* 130, *&c.*

What Mr. *Romer*'s hypotheſis is, may be ſeen in the *Phil. Tranſ.* before cited; as alſo in the before-commended Sir *Iſaac Newton's Optics: Light is propagated from luminous bodies in time, and ſpends about ſeven or eight minutes of an hour in paſſing from the ſun to the earth. This was firſt obſerved by* Romer, *and then by others, by means of the eclipſes of the ſatellites of* Jupiter. *For theſe eclipſes, when the earth is between the* ſun *and* Jupiter, *happen about ſeven or eight minutes ſooner than they ought to do by the tables; and when the* earth *is beyond the* ſun, *they happen about ſeven or eight minutes later than they ought to do: the reaſon being, that the light of the ſatellites hath farther to go in the latter caſe than in the former, by the diameter of the earth's orbit.* Newt. Opt. l. 2. part 3. prop. 11.

Now foraſmuch as the diſtance between the ſun and the earth (according to the computations in my *Aſtro-Theology, b.* 1. *ch.* 3. *note* 2.) is 86,051,398 *Engliſh* miles; therefore, at the rate of ſeven minutes and a half, or 450 ſeconds, in paſſing from the ſun, light will be found to fly above 191,225 miles in one ſecond of time.

(*f*) Dr. *Hook*'s Poſthumous Works, *Lect. of Light*, p. 76.

"ſions

" ſions of man's underſtanding. Inſomuch, that " very many have aſſerted it abſolutely infinite, " and without any limits or bounds."

And that this noble creature of God is of this extent (*g*), is manifeſt from our ſeeing ſome of the fartheſt diſtant objects, the heavenly bodies, ſome

(*g*) For the proof of this vaſt extent of light, I ſhall take the computation of the ſame great man, *p.* 77. *If*, ſaith he, *we conſider firſt the vaſt diſtance between us and the ſun, which, from the beſt and lateſt obſervations in aſtronomy, is judged to be about* 10,000 *diameters of the earth, each of which is about* 7925 Engliſh *miles; therefore the ſun's diſtance is* 7,925,000 *miles; and* 79,2
if we conſider, that, according to the obſervations which I publiſhed to prove the motion of the earth, (which were obſervations of the parallax of ſome of the fixed ſtars in the head of *Draco* made in 1699,) *the whole diameter of the orb*, viz. 20,000, *made the ſubtenſe but of one minute to one of the fixed ſtars, which cannot therefore be leſs diſtant than* 3438 *diameters of this great orb, and conſequently* 68,760,000 *diameters of the earth: and if this ſtar be one of the neareſt, and that the ſtars that are of one degree leſſer in magnitude (I mean not of the ſecond magnitude, becauſe there may be many degrees between the firſt and ſecond) be as much farther; and another ſort yet ſmaller be three times as far; and a fourth four times as far, and ſo onward, poſſibly to ſome* 100 *degrees of magnitude, ſuch as may be diſcovered by longer and longer teleſcopes, that they may be* 100 *times as far; then certainly this material expanſion, a part of which we are, muſt be ſo great, that it will infinitely exceed our ſhallow conception to imagine. Now, by what I laſt mentioned, it is evident, that light extends itſelf to the utmoſt imaginable parts, and by the help of teleſcopes we collect the rays, and make them ſenſible to the eye, which are emitted from ſome of the almoſt inconceivably remote objects*, &c. —*Nor is it only the great body of the ſun, or the vaſt bodies of the fixed ſtars, that are thus able to diſperſe the light through the vaſt expanſum of the univerſe; but the ſmalleſt ſpark of a lucid body muſt do the very ſame thing, even the ſmalleſt globule ſtruck from a ſteel by a flint*, &c.

with

with our naked eye, ſome with the help of optical inſtruments, and others in all probability farther and farther, with better and better inſtruments: and had we inſtruments of power equivalent to the extent of light, the luminous bodies of the utmoſt parts of the univerſe would, for the ſame reaſon, be viſible too.

Now as light is of greateſt uſe to empower us to ſee objects at all, ſo the extenſion thereof is no leſs uſeful to enable us to ſee objects afar off. By which means we are afforded a ken of thoſe many glorious works of the infinite Creator, viſible in the heavens, and can improve them to ſome of the nobleſt ſciences, and moſt excellent uſes of our own globe.

CHAP. V.

Of Gravity.

THE laſt thing ſubſervient to our globe, that I ſhall take notice of, is *Gravity* (*a*); or, that tendency which bodies have to the centre of the earth.

In

(*a*) That there is ſuch a thing as *Gravity*, is manifeſt from its effects here upon earth; and that the heavenly bodies attract or gravitate to one another, when placed at due diſtances, is made highly probable by Sir *Iſaac Newton*. This attractive or gravitating power, I take to be congenial to matter, and imprinted on all the matter of the univerſe by the Creator's *fiat* at the creation. What the *cauſe* of it is, the *Newtonian Philoſophy* doth not pretend to determine for want of phænomena, upon which foundation it is that that philoſophy is grounded, and not upon chimerical and uncertain hypotheſis: but whatever the cauſe is, that *cauſe penetrates even to the centres of the ſun and planets, without any diminution of its virtue; and it acteth not according to the ſuperficies of bodies, (as mechanical cauſes do,) but in proportion to the quantity of their ſolid matter:* and laſtly, *it acteth all round it at immenſe diſtances, decreaſing in duplicate proportion to thoſe diſtances*, as Sir *Iſaac Newton* ſaith, *Princip. pag.* ult. What uſeful deductions, and what a rational philoſophy, have been drawn from hence, may be ſeen in the ſame book.

This attraction, or gravity, as its force is in a certain proportion, ſo it makes the deſcent of bodies to be at a certain rate. And was it not for the reſiſtance of the medium, all bodies would deſcend to the earth at the ſame rate; the lighteſt down, as ſwiftly as the heavieſt mineral: as is manifeſt in the *air-pump*, in which the lighteſt feather, duſt, &c. and a piece of lead, drop

In my *Astro-Theology, book 6. ch. 2.* I have ſhewn of what abſolute neceſſity, and what a noble contrivance this of gravity is, for keeping the

drop down ſeemingly in .the ſame time, from the top to the bottom of a tall exhauſted receiver.

The rate of the deſcent of heavenly bodies, according to *Galilæo*, Mr. *Huyghens*, and Dr. *Halley* (after them) is 16 feet one inch in one ſecond of time; and in more ſeconds, as the ſquares of thoſe times. But in ſome accurate experiments made in St. *Paul*'s *dome*, *June* 9, 1710, at the height of 220 feet, the deſcent was ſcarcely 14 feet in the firſt ſecond. The experiments were made in the preſence of ſome very conſiderable members of the Royal Society, by Mr. *Hawkſhee*, their operator, with glaſs hollow balls, ſome empty, ſome filled with quickſilver, the barometer at 297, the thermometer 60 degrees above freezing. The weight of the balls, their diameters, and time of the deſcent, is in this table.

Balls filled with quickſilver.			Empty balls.			
Weight.	Diameter.	Time.	Weight.	Diameter		Time.
Grains.	Tenth. Inch.	Half Seconds.	Grains.	Inch.	Tenth.	Half Seconds.
908	8	8	510	5	1	17
993	8	8 leſs.	642	5	2	16
866	8	8	599	5	1	16
747	7 & half	8 more.	515	5 nearly		16 & half
808	7 & half	8	483	5 nearly		17
784	7 & half	8 more.	641	5	2	16

The reaſon why the heavy, full balls fell in half the time of the hollow ones, was the reſiſtance of the air: which reſiſtance is very ingeniouſly and accurately aſſigned by Dr. *Wallis*, in *Philoſ. Tranſ.* No. 186. And the cauſe of the reſiſtance of all fluids (as Sir *Iſaac Newton, Opt.* Q. 20.) is partly from the *friction* of the parts of the fluid, partly from the *inertia* thereof. The reſiſtance a ſpherical body meets with from friction, is as the right angle under the diameter, and the velocity of the moving body: and the reſiſtance from the *vis inertiæ*, is as the ſquare of that product.

For

the ſeveral globes of the univerſe from ſhattering to pieces, as they evidently muſt do in a little time, by their ſwift rotation round their own axes (*b*). The terraqueous globe particularly, which circumvolves at the rate of above 1000 miles an hour (*c*), would,

For a farther account of the properties and proportions, *&c.* of Gravity, in the fall or projection of bodies, I ſhall refer to the larger accounts of *Galilæus*, *Torricellius*, *Huygens*, Sir *Iſaac Newton*, &c.; or to the ſhorter accounts of Dr. *Halley*, in *Philoſoph. Tranſ.* abridged by Mr. *Lowthorp*, vol. i. p. 561; or Dr. *Clarke*, in his notes on *Rohault. Phyſ.* 2. *c.* 28. *ſect.* 13, 16. And for the reſiſtance of fluids, I refer to Dr. *Wallis*, before cited, and the *Act. Erudit. Lipſ. May* 1693, where there is a way to find the force of mediums upon bodies of different figures.

(*b*) That the heavenly bodies move round their own axes, is, beyond all doubt, manifeſt to our eye, in ſome of them, from the ſpots viſible on them. The ſpots on the ſun (eaſily viſible with an ordinary glaſs) do manifeſt him to revolve round his own axis in about 25 days and a quarter. The ſpots on *Jupiter* and *Mars* prove thoſe two planets to revolve alſo from eaſt to weſt, as Dr. *Hook* diſcovered in 1664 and 1665. And *Venus* alſo (although near the ſtrong rays of the ſun) hath, from ſome ſpots, been diſcovered by Mr. *Caſſini*, in 1666 and 1667, to have a manifeſt rotation. Vide *Lowthorp's Abridg.* vol. i. p. 382, and 423, 425. And ſuch uniformity hath the *Creator* obſerved in the works of nature, that what is obſervable in one, is generally to be found in all others of the ſame kind. So that ſince it is manifeſt the ſun, and three of his planets whirl round, it is very reaſonable to conclude all the reſt do ſo too; yea, every globe of the Univerſe.

(*c*) The earth's circumference being 25,031 miles and a half (according to *Book* II. *Chap.* 2. *Note* (*a*), if we divide that into 24 hours, we ſhall find the motion of the earth to be near 1043 miles in an hour. Which, by the bye, is a far more reaſonable

would, by the centrifugal force of that motion, be ſoon diſſipated and ſpirtled into the circumambient ſpace, was it not kept together by this noble contrivance of the Creator, this natural inherent power, namely, the power of attraction or Gravity.

And as by this power our globe is defended againſt diſſipation, ſo all its parts are kept in their proper place and order. All material things do naturally gravitate thereto, and unite themſelves therewith, and ſo preſerve its bulk entire (*d*). And

ſonable and leſs rapid rate than that of the ſun would be, if we ſuppoſe the earth to ſtand ſtill, and the ſun to move round the earth. For according to the proportions in note (*e*) of the preceding chapter, the circumference of the *magnus orbis* is 540,686,225 *Engliſh* miles, which divided by 24 hours, gives 22,528,364 miles in an hour. But what is this to the rapidity of the fixed ſtars, if we ſuppoſe them, not the earth, to move? Which is a good argument for the earth's motion.

(*d*) *Nihil majus, quàm quòd ita ſtabilis eſt mundus, atque ita cohæret ad permanendum, ut nihil nè excogitari quidem poſſit aptius. Omnes enim partes ejus undique medium locum capeſſentes, nituntur æqualiter: maximè autem corpora inter ſe juncta permanent, cùm quodam quaſi vinculo circumdata colligantur: quod facit ea natura, quæ per omnem mundum, omnia mente, & ratione conficiens, funditur, & ad medium rapit, & convertit extrema.*—"This world is ſo ſtabliſhed, and remains ſo united by coheſion, that nothing can be conceived more exquiſitely contrived. For all its parts have an equal tendency towards the centre: and bodies remain united by the ſame coheſion, as if bound by a chain: all which is effected by Nature, which having formed every thing by wiſdom and intelligence, and extending her influence over all her works, keeps the whole together by inclining them towards the centre."—*Cic. de Nat. Deor.* l. 2. c. 45.

the

the fleeting waters, the moſt unruly of all its parts, do by this means keep their conſtant equipoiſe in the globe (*e*), and remain in *that place which*, the Pſalmiſt ſaith, *God had founded for them; a bound he had ſet, which they might not paſs; that they turn not again to cover the earth*, Pſal. civ. 8, 9. So, that even in a natural way, by virtue of this excellent contrivance of the Creator, the obſervation of the Pſalmiſt is perpetually fulfilled, *Pſal.* lxxxix. 9. *Thou ruleſt the raging of the ſea; when the waves thereof ariſe, thou ſtilleſt them.*

To theſe, and an hundred other uſes of Gravity that I might have named, I ſhall only juſt mention another thing owing to it, and that is *Levity* (*f*), that whereby what we call light bodies ſwim, a thing no leſs uſeful to the world than its oppoſite, Gravity, is in many reſpects, to divers tribes

(*e*) *Eâdem ratione mare, cum ſupra terram ſit, medium tamen terræ locum expetens, conglobatur undique æqualiter, neque redundat, unquam, neque effunditur.*—"By the ſame law, the ſea, although it be above the earth, yet always tending towards the centre of the globe, forms equally a ſpherical ſurface, and neither runs off nor overflows."—*Id. paulo poſt.*

(*f*) That there is no ſuch thing as *poſitive levity*, but that Levity is only a leſs Gravity, is abundantly manifeſted by the acute *Seig. Alph. Borelli de Mot. à Grav. pend.* cap. 4. See alſo the annotations of the learned and ingenious Dr. *Clark*, on *Rohaulti Phyſ.* p. 1. c. 16. note 3. Alſo the experiments of the *Acad. del Cimento*, p. 118, &c. Dr. *Wallis's Diſcourſe of Gravity and Gravitation before the Royal Society*, Nov. 12, 1674, p. 28, *&c.*

of animals, but particularly ſerviceable to the raiſing up of vapours (*g*), and to their conveyance about the world.

And now from this tranſient view of no other than the out-works, than the bare appendages of the terraqueous globe, we have ſo manifeſt a ſample

(*g*) I have before in *note* (*a*), *ch.* 3. ſhewn what *vapours* are, and how they are raiſed. That which I ſhall here note, is their quantity; concerning which, the before-commended Dr. *Halley* hath given us ſome curious experiments in our *Philoſoph. Tranſ.* which may be met with together in Mr. *Lowthop's Abridg.* vol. ii. p. 108 and 126. Monſ. *Sedileau* alſo at *Paris* obſerved it for near three years. By all their obſervations it appears, that in the winter months the evaporations are leaſt, and greateſt in ſummer, and moſt of all in windy weather. And by Monſ. *Sedileau*'s obſervations it appears, that what is raiſed by vapours, exceeds that which falleth in rain. In the ſeven laſt months of the year 1688, the evaporations amounted to 22 inches five lines; but the rain only to 10 inches ſix lines one-third: in 1689, the evaporations were 32 inches 10 lines and half; but the rain 18 inches one line: in 1690, the evaporations 30 inches 11 lines; the rain 21 inches one-third of a line.—Vide *Mem. de Math. Phyſ. Ann.* 1692, p. 25.

If it be demanded, what becomes of the overplus of exhalations that deſcend not in rain? I anſwer, they are partly tumbled down and ſpent by the winds, and partly deſcend in dews, which amount to a greater quantity than is commonly imagined. Dr. *Halley* found the deſcent of vapours in dews ſo prodigious at *St. Helena*, that he makes no doubt to attribute the origin of fountains thereto. And I myſelf have ſeen in a ſtill, cool evening, large thick clouds hanging, without any motion in the air, which in two or three hours time have been melted down by degrees, by the cold of the evening, ſo that not any the leaſt remains of them have been left.

of the wiſdom, power, and goodneſs of the infinite Creator, that it is eaſy to imagine the whole fabric is of a piece, the work of at leaſt a ſkilful artiſt. A man that ſhould meet with a palace (*b*) beſet with pleaſant gardens, adorned with ſtately avenues, furniſhed with well-contrived aqueducts, caſcades, and all other appendages conducing to convenience or pleaſure, would eaſily imagine, that proportionable architecture and magnificence were within: but we ſhould conclude the man was out of its wits that ſhould aſſert and plead, that all was the work of chance, or other than of ſome wiſe and ſkilful hand. And ſo when we ſurvey the bare out-works of this our globe, when we ſee ſo vaſt a body, accoutered with ſo noble a furniture of Air, Light, and Gravity; with every thing, in ſhort, that is neceſſary to the preſervation and ſecurity of the globe itſelf, or that conduceth to the life, health, and happineſs, to the propagation and increaſe of all the prodigious variety of creatures the globe is ſtocked with; when we ſee nothing wanting, nothing redundant or frivolous, nothing botching or ill-made, but that every thing, even in the very appendages alone, exactly anſwereth all its ends and occaſions: what elſe can be concluded, but that all was made with manifeſt deſign, and that all the whole ſtructure is the work of ſome

(*b*) See book ii. c. iii. note (*c*).

intelligent Being; ſome Artiſt of power and ſkill equivalent to ſuch a work?

NOTE *on the various uſes of the* ELECTRICAL FLUID *in the general ſyſtem of nature.*

Having remarked in a former note, (at p. 30,) that at the time when our excellent author compoſed theſe diſcourſes, a very few only of the moſt trifling phenomena of electricity had been diſcovered; and that it was not till towards the middle of this century, that the identity of the electric fluid with lightning was aſcertained, ſince which time the reſearches of philoſophers have ſhewn the preſence and active influence of this fluid in almoſt all the phenomena and operations of nature; I ſignified my intention of exhibiting, in one point of view, the various phenomena of the natural world in which we can diſcover the operations of the electrical principle: a detail material to the preſent work, as enabling the reader to correct ſome erroneous opinions of the author, particularly in this firſt book, which have ariſen from the comparatively imperfect ſtate of certain branches of natural knowledge in his time, which of late have been cultivated with conſiderable ardour and proportional ſucceſs.

The experiments of Mr. Sauſſure, M. Volta, and others, as ſhortly enumerated in the Encyclopedia Britannica, article *Electricity*, ſhew that this principle is concerned in the production of clouds, rain, hail, ſnow, &c. If water is evaporated by heat, a great portion of electrical fluid is produced. When vapour is condenſed into rain, a quantity of electricity is likewiſe produced; for clouds when falling down in rain emit the electrical fluid in great quantity, and in proportion to the maſs of water diſcharged, as we obſerve in thunder ſtorms. Small clouds floating in the atmoſphere, are often ſeen to attract each other and ſo meet together; after which, if they have been nearly of an equal ſize, both will almoſt inſtantly vaniſh. Many experiments concur to ſhew, that the tranſparency of various

various ſubſtances depends on the vibratory motion of the electric fluid. Thus metals, wax, and other opaque ſubſtances, when the electric fluid pervades them in great quantity, become tranſparent. In the caſe of vapour diffuſed in the atmoſphere, therefore, as long as this vibratory motion is continued through it, the vapour remains diſſolved and tranſparent; but when the electric fluid runs in a ſtream, the vapour loſes its tranſparency, and appears in the form it was originally raiſed by heat, viz. that of an opaque ſmoke or miſt. In this form the electric fluid begins to exert its attractive power, clouds meet each other, and reciprocally emit and receive the ſurcharge of fluid which they contain; a colliſion which, if violent, exhibits the phenomena of thunder and lightning.

It is proved that the electric fluid and the light of the ſun are the ſame; the former being no other than the ſolar light abſorbed by the earth, entangled among its particles, and becoming ſubject to new laws, and acting in many caſes, as if it were a diſtinct fluid. Hence as light is the electric fluid moving in a vibratory manner, and what we call electricity is the ſame fluid either in a comparatively ſtagnant ſtate, or paſſing violently from one place to another; the light and electricity become antagoniſts to each other: and as the action of light when augmented is *heat*, the former which oppoſes, *i.e.* the electric fluid moving in an oppoſite direction, is *cold* itſelf. The electric fluid, therefore, regulates the light and heat of the ſun through the whole ſyſtem, and is itſelf regulated by them, ſo that neither heat nor cold can ultimately predominate any where.

The electric fluid is known to produce earthquakes, and to kindle volcanoes. It acts independent of the air, and cannot have its motions controlled by it. A ſtream of electric light cannot be turned aſide by the ſtrongeſt blaſt of a bellows; but on the contrary, if an attracting ſubſtance is preſented on the other ſide of the blaſt, will paſs through it as if it had met with no oppoſition. As the electric fluid, therefore, acts independent of the air, and cannot have its

motions controlled by it, it is highly probable, that all the motions of the atmofphere are controlled by this fluid alone.

Many experiments have fhewn, that vegetation is promoted by the electric fluid, and obftructed by its abfence. The Abbé Bertholon has fhewn various eafy methods of communicating this fluid to vegetables by electrified water.

The electric fluid exifts in the bodies of all living animals. It was firft fenfibly afcertained by the phenomenon of fparks iffuing from the fur of a cat, when rubbed with a warm hand in the dark; and thefe accompanied with a crackling found. Wild animals, when in purfuit of their prey in the night, are obferved to emit an electric flafhing from their bodies, and from their eyes; and this light, Dr. Prieftley conjectures, may affift them in catching their prey. Mr. Brydone remarked electric fparks to proceed from the hair of a young lady, when combing in the dark in frofty weather; and having defired one lady to ftand on a cake of wax, and comb the other's hair, who was fitting in a chair before her; the lady who ftood on the wax, as foon as fhe began to comb, darted out fparks of fire all around her; and from her hair Mr. Brydone charged an electric jar. Similar phenomena of a yet more furprifing appearance are defcribed in a letter from Mr. Æpinus, profeffor of the Imperial academy at St. Peterfburgh, to Dr. Guthrie, publifhed in the 2d volume of the Tranfactions of the Royal Society of Edinburgh.—The electric fluid in its moft active ftate is well known to refide in two particular fpecies of fifhes, the Gymnotus and the Torpedo; both of which when touched or even approached by the hand, or by an iron rod held in the hand, give a very fmart and painful fhock, which may be communicated like that from the Leyden phial to as many as join hands, or act in contact with each other. In thefe animals this electrical quality is conftantly prefent, and is an inftrument of defence againft their enemies.

The phenomena of magnetifm are known to depend on electricity. Magnetic needles may be endowed with their virtue by artificial electricity, and iron rods have been known to receive

receive it from lightning; whence it is reaſonable to conclude, that the power of the magnet at all times depends on the ſecret operation of the electric fluid. By extending its powers to the production of attractive and repulſive forces, in all caſes, which we are encouraged to do from many natural phenomena, we are led to aſſign it an agency in regulating even the motions of the planets; and we may preſume, that it is this principle which gives ſtability and coheſion, not only to all terreſtrial ſubſtances, but to the globe of the earth itſelf, and all other bodies in the univerſe. EDITOR.

BOOK II.

Of the Terraqueous Globe itſelf in general.

IN the foregoing Book having diſpatched the out-works, let us take a ſurvey of the principal fabric, *viz.* the *Terraqueous Globe* itſelf; a moſt ſtupendous work in every particular of it, which doth no leſs aggrandize its Maker (*a*), than every curious,

(*a*) *Licet —— oculis quodammodo contemplari pulchritudinem earum rerum, quas Divinâ Providentiâ dicimus conſtitutas. Ac principio terra univerſa cernatur, locata in mediâ mundi ſede, ſolida, & globoſa—veſtita floribus, herbis, arboribus, frugibus; quorum omnium incredibilis multitudo, inſatiabili varietate diſtinguitur. Adde huc fontium gelidas perennitates, liquores perlucidos amnium, riparum veſtitus veridiſſimos, ſpeluncarum concavas altitudines, ſaxorum aſperitates, impendentium montium altitudines, immenſitateſque camporum: adde etiam reconditas auri—venas— Quæ verò & quàm varia genera beſtiarum?—Qui volucrûm lapſus, atque cantus? Qui pecudum paſtus?—Quid de hominum genere dicam? Qui quaſi cultores terræ conſtituti, &c.—Quæ ſi, ut animis, ſic oculis videre poſſemus, nemo cunctam intuens terram, de Divinâ ratione dubitaret.*—“ We may contemplate with our eyes the beauty of thoſe works which are framed by the Divine Providence. And in the firſt place, let us view the earth, fixed in the centre of the univerſe, ſolid and globular:— clad with flowers, with herbs, with trees and fruits; an incredible multitude, yet diſtinguiſhed by an endleſs variety.— Conſider

ous, complete work doth its workmen. Let us caſt our eyes here and there, let us ranſack all the globe, let us with the greateſt accuracy inſpect every part thereof, ſearch out the inmoſt ſecrets of any of the creatures; let us examine them with all our gauges, meaſure them with our niceſt rules, pry into them with our microſcopes, and moſt exquiſite inſtruments (*b*), ſtill we find them to bear teſtimony to their infinite Workman; and that they exceed all human ſkill ſo far, as that the moſt exquiſite copies and imitations of the beſt artiſts are

Conſider the perpetual cooling ſprings, the pellucid rivers, the green margins of the brooks, the profound caverns, the craggy rocks, the towering mountains, and wide-extended plains.—Conſider the internal treaſures of the earth, the veins of hidden gold.—Examine the infinite variety of animals, the flight and the ſong of birds, the food of cattle.—Why ſhould I add the human race, who are appointed to cultivate the earth, &c.?—Could we view all theſe with the eye of the underſtanding, as we perceive them with the natural eye, there is none who, thus ſurveying the univerſe, could entertain a doubt of the wiſdom and intelligence of its Divine Author.—*Cic. de Nat. Deor.* l. 2. c. 39.

(*b*) *I cannot here omit the obſervations that have been made in theſe latter times, ſince we have had the uſe and improvement of the* Microſcope, *concerning the great difference, which by the help of that, doth appear betwixt* natural *and* artificial *things. Whatever is natural, doth by that appear adorned with all imaginable elegance and beauty.—Whereas the moſt curious works of art, the ſharpeſt, fineſt needle, doth appear as a blunt, rough bar of iron coming from the furnace or the forge. The moſt accurate engravings or emboſſments ſeem ſuch rude, bungling, deformed works, as if they had been done with a mattock or a trowel. So vaſt a difference is there betwixt the ſkill of* Nature *and the rudeneſs and imperfection of* Art.—*Biſhop* Wilk. Nat. Rel. *l.* 1. *ch.* 6.

no

no other than rude bungling pieces to them. And ſo far are we from being able to eſpy any defect or fault in them, that the better we know them, the more we admire them; and the farther we ſee into them, the more exquiſite we find them to be.

And for a demonſtration of this I ſhall,

I. Take a general proſpect of the Terraqueous Globe.

II. Survey its particulars.

I. The things which will fall under a general proſpect of the globe, will be its *Figure*, *Bulk*, *Motion*, *Place*, *Diſtribution* into earth and waters, and the great *Variety* of all things upon it and in it.

CHAP. I.

Of the Figure of the Terraqueous Globe.

THIS I ſuppoſe I may take for granted to be ſpherical, or nearly ſo (*a*). And this muſt be allowed to be the moſt commodious, apt figure for a world on many accounts; as it is moſt capacious, as

(*a*) Although the terraqueous globe be of an orbicular figure, yet it is not ſtrictly ſo: 1. On account of its hills and vallies. But theſe are inconſiderable to the earth's ſemi-diameter; for they are but as the duſt upon a common globe. But, 2. Our modern aſtronomers aſſign a much greater variation from a globous form, namely, that of a prolate ſphæroid, making the polar about 34 miles ſhorter than the equatorial diameter. The cauſe of which they make to be the centrifugal force of the diurnal rotation of the globe.

This figure they imagine is in *Jupiter*, his polar being to his equatorial diameter, as 39 three-fifths to 40 three-fifths. But whether it be ſo or no, I confeſs I could never perceive, although I have often viewed that planet through very good and long glaſſes, particularly a tolerable good one of 72 feet in my hands: and although by reaſon of cloudy weather, and (at preſent) *Jupiter*'s proximity to the ſun, I have not been of late able to take a review of that planet; yet *Saturn* (ſo far as his ring would permit) and *Mars* appear perfectly round, through Mr. *Huygens*'s long glaſs of 126 feet, which by will he bequeathed, with its whole apparatus, to our *R. S.* by whoſe favour it is now in my hands. And moreover, I believe it difficult, next to impoſſible, to meaſure the two diameters to a 40th part, by reaſon of the ſmallneſs of *Jupiter*'s apparent diameter, and by reaſon he is moving all the time of meaſuring him.

As

as its furface is equi-diftant from the centre, not only of the globe, but at leaft (nearly) of gravity and motion too, and, as fome have thought, of the central heat and waters. But thefe and divers other things I fhall pafs over, and infift only upon two or three other benefits of this globous figure of the earth and waters.

As to what is alleged from lengthening the pendulums of clocks, to make them keep the fame time under the equator, as they do in our climes; I have fhewn from the like variations in the air-pump, that this may arife from the rarity of the air there, more than here. Vide *Phil. Tranf.* No. 294. But if the degrees of a meridian grow larger, the more we go towards the line, (as Mr. *Caffini* affirms they do, by an 800th part in every degree, in *Phil. Tranf.* No. 278.) then there is great reafon to conclude in behalf of this fphæroidal form.

The natural caufe of this fphericity of our globe, is (according to Sir *Ifaac Newton*'s principles) that *attraction* which the infinite Creator hath ftamped on all the matter of the univerfe, whereby all bodies, and all the parts of bodies, mutually attract themfelves, and one another. By which means, as all the parts of bodies tend naturally to their centre, fo they all betake themfelves to a globous figure, unlefs fome other more prevalent caufe interpofe. Thus drops of quickfilver put on a fpherical form, the parts thereof ftrongly attracting one another. So drops of water have the fame form when falling in the air; but are hemifpherical only when they lie on a hard body, by reafon their gravity doth fo far overpower their felf-attracting power, as to take off one-half of their fphericity. This figure is commonly attributed to the preffure of the circumambient air: but that this cannot be the caufe, is manifeft from the air-pump; the cafe being the very fame in an exhaufted receiver, as in the open air, and not any the leaft alteration of the figure that I could perceive, in all the trials I have made.

1. This

1. This figure is the moſt commodious in regard of heat, and I may add of light alſo in ſome meaſure: for by this means, thoſe two great benefits are uniformly and equally imparted to the world; they come harmoniouſly and gradually on, and as gradually go off again. So that the daily and yearly returns of light and darkneſs, cold and heat, moiſt and dry, are regular and workman-like, (we may ſay,) which they would not be, eſpecially the former, if the maſs of earth and waters were (as ſome fancied (*b*) it) a large plain; or as others, like a large hill in the midſt of the ocean; or of a multangular figure; or ſuch like.

2. This figure is admirably adapted to the commodious and equal diſtribution of the waters in the globe. For ſince, by the laws of gravity, the waters will poſſeſs the loweſt place; therefore, if the maſs

(*b*) It would be frivolous, as well as endleſs, to reckon up the various opinions of the ancients about the figure of the terraqueous globe; ſome of them may be ſeen in *Varen. Geogr.* l. i. c. 3. *init.* or *Johnſton's Thaumat.* c. 1. *artic.* 3. But among the variety of opinions, one of the principal was, That the viſible horizon was the bounds of the earth, and the ocean the bounds of the horizon; that the heavens and earth above this ocean was the whole viſible univerſe; and that all beneath the ocean was *Hades*, or the *inviſible world*. Hence, when the Sun ſet, he was ſaid *tingere ſe oceano*; and when any went to *Hades*, they muſt firſt paſs the ocean. Of this opinion were not only the ancient poets, and others among the Heathens, but ſome of the Chriſtian fathers too, particularly *Lactantius*, St. *Auguſtine*, and others, who thought their opinion was favoured by the Pſalmiſt, in *Pſalm* xxiv. 2. and cxxxvi. 6.—See *Bp. Uſher's Anſ. to a Jeſ. Chall.* p. 366. &c.

of

of the earth was cubic, priſmatic, or any other angular figure, it would follow, that one (too vaſt a part) would be drowned; and another be too dry. But being thus orbicular, the waters are equally and commodiouſly diſtributed here and there, according as the Divine Providence ſaw moſt fit; of which I ſhall take notice by and by.

3. The orbicular figure of our globe is far the moſt beneficial to the winds and motions of the atmoſphere. It is not to be doubted, if the earth was of ſome other, or indeed any other figure, but that the currents of air would be much retarded, if not wholly ſtopped. We find by experience, what influence large and high mountains, bays, capes, and head-lands have upon the winds; how they ſtop ſome, retard many, and divert and change (near the ſhores) even the *general* and *conſtant winds* (*c*), that

(*c*) *Neither do theſe conſtant* trade winds *uſually blow near the ſhore, but only on the ocean, at leaſt* 30 *or* 40 *leagues off at ſea, clear from any land; eſpecially on the weſt coaſt, or ſide of any continent: for indeed on the eaſt ſide, the eaſterly wind, being the true trade wind, blows almoſt home to the ſhore, ſo near as to receive a check from the land wind.*—Dampier's Winds, ch. 1.

And not only the *general trade winds*, but alſo the *conſtant coaſting trade winds*, are in like manner affected by the lands: thus for inſtance, on the coaſt of *Angola* and *Peru*. But this, ſaith the curious captain *Dampier*, the reader muſt take notice of, *That the trade winds that blow on any coaſt, except the north coaſt of* Africa, *whether they are conſtant, and blow all the year, or whether they are ſhifting winds, do never blow right in on the ſhore, nor right along ſhore, but go ſlanting, making an acute angle of about* 22 *degrees. Therefore, as the land tends more eaſt or weſt, from north or ſouth on the coaſt, ſo the winds do alter accordingly.*—Ibid. ch. 2.

blow

blow round the globe in the torrid zone. And therefore, ſince this is the effect of ſuch little excreſcences, which have but little proportion to our globe, what would be the conſequences of much vaſter angles, which would equal a quarter, tenth, or but an hundredth part of the globe's radius? Certainly theſe muſt be ſuch a barricade, as would greatly annoy, or rather abſolutely ſtop the currents of the atmoſphere, and thereby deprive the world of thoſe ſalutiferous gales that I have ſaid keep it ſweet and clean.

Thus the figure of our globe doth manifeſt it to be a work of contrivance, inaſmuch as it is of the moſt commodious figure; and all others would be liable to great and evident inconveniences.

CHAP. II.

Of the Bulk of the terraqueous Globe.

THE next thing remarkable in the terraqueous globe, is the prodigious bulk thereof (*a*) :—a mafs of above 260 thoufand million of miles folid content :—awork too grand for any thing lefs than a God to make. To which in the next place we may add,

(*a*) It is not difficult to make a pretty near computation of the bulk of the terraqueous globe, from thofe accurate obferva-tions of a degree made by Mr. *Norwood* in *England*, and Mr. *Picart* and Mr. *Caffini* in *France*. Whofe meafures do in a furprifing manner agree. But Mr. *Caffini*'s feeming to be the moft accurate, (as I have fhewn in my *Aftro-Theology*, b. 1. ch. 2. note (*a*),) I have there made ufe of his determinations. According to which the diameter of the earth being 796,772 *Englifh* miles, its ambit will be 25,031 miles and half; and (fuppofing it to be fpherical) its furface will be 199,444,220 miles; which being multiplied into one third of its femidiameter, gives the folid content, *viz.* 264,856,000,000 miles.

CHAP. III.

The Motions of the terraqueous Globe.

THE motions the terraqueous globe hath, are round its own axis, and round its fountain of light and heat, the ſun (*a*). That ſo vaſt a body as the earth and waters ſhould be moved at all (*b*), that

(*a*) With the *Copernicans*, I take it here for granted, that the diurnal and annual revolutions are the motions of the terraqueous globe, not of the ſun, &c. but for the proof thereof I ſhall refer the reader to the preface of my *Aſtro-Theology*, and b. iv. c. 3.

(*b*) *Every thing that is moved, muſt of neceſſity be moved by ſomething elſe; and that thing is moved by ſomething that is moved either by another thing, or not by another thing. If it be moved by that which is moved by another, we muſt of neceſſity come to ſome* prime mover, *that is not moved by another, for it is impoſſible, that what moveth and is moved by another, ſhould proceed* in infinitum. Ariſtot. Phyſ. l. 8. c. 5.

Solum quod ſeipſum movet, quia nunquam deſeritur à ſe, nunquam ne moveri quidem deſinit: quinetiam cæteris quæ moventur, hic fons: hoc principium eſt movendi. Principii autem nulla eſt origo: nam ex principio oriuntur omnia; ipſum autem nullâ ex re aliâ naſci poteſt: nec enim eſſet id principium, quod gigneretur aliunde.—"That only which moves itſelf, never ceaſes to move; for it cannot be abandoned by itſelf: but this likewiſe is the ſpring and principle of motion in other things. But a firſt principle can have no origin; for the principle is the origin of every thing, and can itſelf ariſe from nothing elſe; for if it aroſe from any thing elſe, it would not be a principle."—*Cicer. Tuſc. Queſt.* l. 1. c. 23.

Cogitemus qui fieri poſſit, ut tanta magnitudo, ab aliquâ poſſit natura, tanto tempore circumferri? Ego igitur aſſero Deum cauſam eſſe,

that it ſhould undergo two ſuch different motions, as the diurnal and annual are, and that theſe motions ſhould be ſo conſtantly and regularly (*c*) performed for near 6000 years, without any the leaſt alteration ever heard of (except ſome hours which we read of in *Joſh.* x. 12, 13. and in *Hezekiah*'s time, which, if they cannot be accounted for ſome other way, do greatly encreaſe the

nec aliter poſſe fieri.—" Let us think how it could poſſibly happen that a body of ſuch bulk ſhould revolve in ſuch a ſpace of time. I therefore aſſert that God is the cauſe; nor is it poſſible it could have happened from any other cauſe."—*Plato in Epinom.*

(*c*) Among the cauſes which *Cleanthes* is ſaid in *Tully* to aſſign for men's belief of a Deity, one of the chief is, *Æquabilitatem motûs, converſionem cœli, ſolis, lunæ, ſiderumque omnium diſtinctionem, varietatem, pulchritudinem, ordinem: quarum rerum aſpectus ipſe ſatis indicaret, non eſſe ea fortuita. Ut ſiquis in domum aliquam, aut in gymnaſium, aut in forum venerit; cùm videat omnium rerum rationem, modum, diſciplinam, non poſſit ea ſine causâ fieri judicare, ſed eſſe aliquem intelligat, qui præſit, & cui pareatur: multo magis in tantis motibus, tantiſque viciſſitudinibus, tam multarum rerum atque tantarum ordinibus, in quibus nihil unquam immenſa & infinita vetuſtas mentita ſit, ſtatuat neceſſe eſt ab aliquâ mente tantos naturæ motus gubernari.*—" The equable motion and revolution of the firmament, the ſun, the moon, and the ſtars; the diſtinction, the variety, the beauty, the order of all theſe objects. As if any one ſhould come into a houſe, a hall of exerciſe, or a public aſſembly, and there ſee the arrangement, method, and diſcipline of every thing around him, he would never judge, that theſe things were without cauſe; but would immediately conclude, that there was ſome one who preſided, and to whom all gave obedience: ſo when we behold theſe various motions and changes, and the order of ſuch numerous and immenſe bodies, in which, during the infinite revolution of ages Nature has never erred or failed: with much more reaſon

the wonder (*d*); these things, I say,) do manifestly argue some divine infinite power to be concerned therein (*e*): but especially, if to all this we

reason must we conclude, that these are governed and directed by an Almighty mind."—*Cic. de Nat. Deor.* l. 2. c. 5.

Homines cœperunt Deum agnoscere, cùm viderent stellas, tantam concinnitatem efficere; ac dies, noctesque, æstate, & hyeme, suos servare statos ortus, atque obitus.—"Men began to acknowledge a God, when they beheld the stars, so admirable in the order of their motions, and the regularity with which the day and night, the summer and winter, preserve their stated seasons."—*Plut. de Placit.* l. 1. c. 6.

(*d*) We need not be sollicitous to elude the history of these miracles, as if they were only poetical strains, as *Maimonides* and some others fancy *Joshua*'s day to have been, *viz.* only an ordinary summer's day; but such as had the work of many days done in it; and therefore by a poetical stretch made, as if the day had been lengthened by the sun standing still. But in the history they are seriously related, as real matters of fact, and with such circumstances as manifest them to have been miraculous works of the Almighty: and the prophet *Habakkuk*, iii. 11. mentions that of *Joshua* as such. And therefore taking them to be miraculous perversions of the course of Nature, instead of being objections, they are great arguments of the power of God: for, in *Hezekiah*'s case, to wheel the earth itself backward, or by some extraordinary refractions, to bring the sun's shadow backward 10 degrees; or in *Joshua*'s case, to stop the diurnal course of the globe for some hours, and then again give it the same motion; to do, I say, these things, required the same infinite power which at first gave the terraqueous globe its motions.

(*e*) *Nam cùm dispositi quæsissem fœdera mundi,*
Præscriptosque maris fines, annique meatus,
Et lucis, noctisque vices: tunc omnia rebar
Consilio firmata Dei, qui lege moveri

Sidera,

we add the wonderful convenience, yea abſolute neceſſity of theſe circumvolutions to the inhabitants, yea all the products of the earth and waters. For to one of theſe we owe the comfortable changes of day and night; the one for buſineſs, the other for repoſe (*f*); the one for man, and moſt other animals to gather and provide food,

Sidera, qui fruges diverſo tempore naſci,
Qui variam Phœben alieno juſſerit igne
Compleri, ſolemque ſuo; porrexerit undis
Littora; tellurem medio libraverat axe.

" When firſt my anxious thought explor'd the cauſe
Of theſe effects, and ſearch'd out Nature's laws;
Gueſs'd how the year its ſtated term ſhould keep;
Who fix'd the limits of the ſurgy deep;
What power had form'd the circling orbs of light,
And ſpread the ſable curtain of the night;
No more in miſty paths of doubt I trod;
My reaſon ſaw, my ſoul confeſs'd a God.
Form'd by his hand, thoſe orbs their courſe maintain;
The night, the day with equal empire reign;
The ſun his warmth benign, and radiance yields,
With borrow'd light pale Luna paints the fields;
The ſwelling ſeas th' oppoſing ſhores withſtand,
And earth is poiz'd by an Almighty hand."

Claudian in Rufin. l. 1. *initio.*

(*f*) *Diei noctiſque viciſſitudo conſervat animantes, tribuens aliud agendi tempus, aliud quieſcendi. Sic undique omni ratione concluditur, mente, conſilioque divino omnia in hoc mundo ad ſalutem omnium, conſervationemque admirabiliter adminiſtrari.*—" The viciſſitude of day and night preſerves all the animal creation, by allotting one ſeaſon for action, and another for reſt. Thus, on all hands, we muſt in reaſon conclude, that the ſafety and preſervation of every thing is moſt admirably provided for."—*Cic. de Nat. Deor.* l. 2. c. 53.

 habit-

habitation, and other neceſſaries of life; the other to reſt, refreſh, and recruit their ſpirits (g), waſted with the labours of the day. To the other of thoſe motions we owe the ſeaſons of ſummer and winter, ſpring and autumn, together with the beneficial inſtances and effects which theſe have on the bodies and ſtate of animals, vegetables, and all other things, both in the torrid, temperate, and frigid zones.

(g) The acute Dr. *Cheyne*, in his ingenious *Philoſ. Princ. of Natural Religion*, among other uſes of day and night, ſaith, the night is moſt proper for ſleep; becauſe when the ſun is above the horizon, ſleep is prejudicial, by reaſon the perſpirations are then too great. Alſo that nutrition is moſtly, if not altogether, performed in time of reſt; the blood having too quick a motion in the day; for which reaſon, weak perſons, children, &c. are nouriſhed moſt, and recruit beſt by ſleep.

CHAP. IV.

Of the Place and Situation of the terraqueous Globe, in respect of the heavenly Bodies.

ANother thing very confiderable in our globe, is its place and fituation at a due diftance from the fun (*a*), its fountain of light and heat * ; and

(*a*) It is a manifeft fign of the Creator's management and care, in placing the terraqueous globe at that very diftance it is from the fun, and contempering our own bodies, and all other things, fo duly to that diftance. For was the earth farther from the fun, the world would be ftarved and frozen with cold: and was it nigher, we fhould be burnt, at leaft the moft combuftible things would be fo, and the world would be vexed with perpetual conflagrations. For we fee that a few of the rays of the fun, even no more than what fall within the compafs of half an inch or an inch in a burning-glafs, will fire combuftible bodies, even in our own climate.

* The following obfervation of Sir Ifaac Newton is clearly demonftrative of the admirable wifdom of the Creator, in the fituation which he has affigned to this globe with refpect to the other planets and to the fun. "Thofe planets have the greater denfity, *cæteris paribus*, which are placed neareft the fun: Thus *Jupiter* is more denfe than *Saturn*, and the *Earth* more denfe than *Jupiter*; for it was neceffary to place the planets at different diftances from the fun, that each might receive a greater or a lefs degree of his heat, according to its denfity. If our earth were placed in the orbit of Saturn, the water of it would be frozen up; and if in the orbit of Mercury, it

and from its neighbouring planets of the ſolar ſyſtem, and from the fixed ſtars. But theſe things I have ſpoken more largely of in my *Survey of the Heavens* (*b*), and therefore only barely mention them now; to inſiſt more largely upon,

(*b*) *Aſtro-Theology*, book vii. chap. 7.

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would preſently exhale in vapour. For the ſun's light, to which his heat is proportionable, is ſeven times more denſe in the orbit of *Mercury* than with us; and I have found by the thermometer, that water will boil with a heat ſeven times as great as that of the ſummer's ſun. But the matter of *Mercury* is doubtleſs fitted for heat; and, therefore, muſt be denſer than that of our earth; ſince all denſe matter requires a greater degree of heat to perform the operations of Nature."—*Newton's Princip.* p. 372. EDITOR.

CHAP. V.

The Diſtribution of Earth and Waters.

THE diſtribution of the waters and the dry land, although it may ſeem rude and undeſigned to a careleſs view, and is by ſome taxed as ſuch (*a*), yet

(*a*) The moſt eminent author I have met with, that finds fault with the diſtribution of the earth and waters, and indeed with the whole preſent ſtructure of the globe, is the learned and eloquent theoriſt Dr. *Burnet*, who frequently exclaims on this point: *Tellus noſtra, ſi totam ſimul complectamur, non eſt ordinata & venuſta rerum compages—ſed moles aggeſta vario, incertoque ſitu partium, nullâ ordinis aut venuſtatis habitâ ratione.* Theor. Sacr. l. 1. c. 7. *Ecquis autem à Deo hæc ita facta?* &c. Ib. *Quo autem Herculeo labore opus eſſet ad excavandam terram in tantum hiatum?—Si immediatè à Causâ Primâ effectus fuiſſet hic alveus, aliquem ſaltem ordinem, menſuram, & proportionem notare voluiſſet in ipſius formâ, & partium diſpoſitione;—ſed confuſa omnia,* &c. Ib. c. 8. *Tellus noſtra cùm exigua ſit; eſt etiam rudis: et in illâ exiguitate multa ſunt ſuperflua, multa inelegantia. Dimidiam terræ ſuperficiem inundat oceanus; magnâ ex parte, ut mihi videtur, inutilis.*—" Our earth, if we conſider it altogether, is not a well-ordered and beautiful ſtructure, but a maſs heaped together at random without any regard to order or beauty. But can any one believe, that things were thus made by the hand of God?—What a Herculean labour muſt it have been to hollow out the earth to ſuch a depth? If this bed had been the immediate operation of the Firſt Cauſe, we muſt have obſerved ſome order, ſome meaſure and proportion in its form, and in the diſpoſition of its parts; but all things are confuſed, &c.—Our earth is not only ſmall, but rude in its ſtructure: and

yet is admirably well adjufted to the ufes and conveniences of our world.

For in the firft place, the diftribution is fo well made, the earth and waters fo handfomely, fo workman-like laid, every where all the world over, that there is a juft equipoife of the whole globe. The *Northern* balanceth the *Southern ocean*, the *Atlantic*, the *Pacific fea*. The *American dry land*, is a counterpoife to the *European*, *Afiatic*, and *African*.

In the next place, the earth and the waters are fo admirably well placed about in the globe, as to be helpful to one another, to minifter to one another's ufes. The great oceans, and the leffer feas and lakes, are fo admirably well diftributed throughout the globe (*b*), as to afford fufficient vapours

and even fmall as it is, there are in it many things fuperfluous, and many inelegant. The ocean overflows one half of the furface of the globe; a thing which, to me, appears in a great meafure ufelefs."—And then he goes on to fhew how this part of the Creation might be mended. *Ib. c.* 19. All this is to me furprifing from an author of great ingenuity, who feems in his book to have a juft opinion of and due veneration for God. But certainly fuch notions are very inconfiftent with the belief of God's creating, efpecially his governing and ordering the world. But fuppofe the terraqueous globe was fuch a rude, confufed, inconvenient mafs, as he pretends, yet it is well enough for a finful world. But befides, what others have long ago abundantly anfwered, the following furvey, will, I hope, fufficiently manifeft it to be the work of a wife and beneficent, as well as omnipotent Creator.

(*b*) Some have objected againft the diftribution of the earth and waters, as if the waters occupied too large a part of the globe,

vapours (*c*), for clouds and rains, to temperate the

globe, which they think would be of greater uſe if it was dry land. But then they do not conſider that this would deprive the world of a due quantity of vapours and rain. For if the cavities which contain the ſea, and other waters, were deeper, although the waters were no leſs in quantity, only their ſurfaces narrower and leſſer, the evaporations would be ſo much the leſs, inaſmuch as thoſe evaporations are made from the ſurface, and are, conſequently, in proportion to the ſurface, not the depth or quantity of water.

(*c*) I took notice before, in *Book* I. *Chap.* iii. *note* (*a*), that the vapours conſtituting clouds and rain, are *veſiculæ* of water detached by heat. The manner of which I conceive to be thus; heat being of an agile nature, or the lighteſt of all bodies, eaſily breaks looſe from them; and if they are humid, in its paſſage, carries along with it particles, or little caſes of the water; which being lighter than air, are buoyed up thereby, and ſwim in it; until by knocking againſt one another, or being thickened by the cold, (as in the note before cited,) they are reduced into clouds and drops.

Having mentioned the manner how vapours are raiſed, and there being more room here than in the note before-cited, I ſhall, for the illuſtration of Nature's proceſs, take notice of three things obſervable to our purpoſe, in water over the fire. 1. That the evaporations are proportional to the heat aſcending out of the water. A ſmall heat throws off but few vapours, ſcarce viſible: a greater heat, and aſcending in greater quantities, carries off groſſer, larger, and more numerous *veſiculæ*, which we call a *ſteam*: and if the heat breaks through the water with ſuch a fury, as to lacerate and lift up great quantities or bubbles of water, too heavy for the air to carry or buoy up, it cauſeth what we call *boiling*. And the particles of water thus mounted up by the heat, are viſible ſphærules of water, if viewed with a microſcope, as they ſwim about in a ray of the ſun let into a dark room, with warm water underneath; where ſome of the vapours appear large, ſome ſmaller ſphærules,

the cold (*d*) of the northern frozen air, to cool and

fphærules, according (no doubt) to the larger and leffer quantities of heat blowing them up and carrying them off. 2. If thefe vapours be intercepted in their afcent by any context, efpecially cold body, as glafs, marble, &c. they are thereby reduced into drops, and maffes of water, like thofe of rain, *&c.* 3. Thefe vapours in their afcent from the water, may be obferved, in cold frofty weather, either to rife but a little above the water, and there to hang, or to glide on a little above its furface: Or if the weather be very cold, after a little afcent, they may be feen to fall back again into the water; in their afcent and defcent defcribing a curve fomewhat like that of an arrow from a bow. But in a warmer air, and ftill, the vapours afcend more nimbly and copioufly, mounting up aloft, till they are out of fight. But if the air be warm and windy too, the vapours are fooner carried out of fight, and make way for others. And accordingly I have often obferved, that hot liquors, if not fet too thin, and not frequently ftirred, cool flower in the greateft frofts, than in temperate weather, efpecially if windy. And it is manifeft by good experiments, that the evaporations are lefs at thofe times than thefe; lefs by far in the winter than the warmer months.

(*d*) As our northern iflands are obferved to be more temperate than our continents, (of which we had a notable inftance in the great froft in 170⅚, which *Ireland* and *Scotland* felt lefs of, than moft parts of *Europe* befides; of which fee *Book* IV. *Chap.* xii. *note* (*c*),) fo this temperature is owing to the warm vapours afforded chiefly by the fea, which by the preceding note muft neceffarily be warm, as they are vapours, or water inflated by heat.

The caufe of this heat I take to be partly that of the fun, and partly fubterraneous. That it is not wholly that of the fun, is manifeft from vapours being as or more copioufly raifed when the fun-beams are weakeft as when ftrongeft, there being greater rains and winds at the one time than the other. And that there is fuch a thing as *fubterraneous heat* (whether central, or from the meeting of mineral juices; or fuch as is congenial or

and mitigate the heats (*e*) of the torrid-zone, and to refresh the earth with fertile showers; yea, in some measure to minister fresh waters to the fountains and rivers. Nay, so abundant is this great blessing, which the most indulgent Creator hath afforded us by means of this distribution of the waters I am speaking of, that there is more than a scanty, bare provision, or mere sufficiency; even a

or connatural to our globe, I have not time to inquire; but I say, that such a thing is) is evident not only from the hot-baths, many fiery eruptions and explosions, &c. but also from the ordinary warmth of cellars and places under ground, which are not barely comparatively warm, but of sufficient heat to raise vapours also: as is manifest from the smoking of perennial fountains in frosty weather, and water drawn out of pumps and open wells at such a time. Yea, even animals themselves are sensible of it, as particularly *moles*, who dig before a thaw, and against some other alterations of the weather; excited, no doubt, thereunto by the same warm vapours arising in the earth, which animate them, as well as produce the succeeding changes of the weather.

(*e*) Besides the *trade winds*, which serve to mitigate the excessive heats in the torrid-zone; the clouds are a good screen against the scorching sun-beams, especially when the sun passeth their zenith; at which time is their winter, or coolest season, by reason they have then most clouds and rain. For which service, that which *Varene* takes notice of, is a great providence of God, viz. *Pleraque loca zonæ torridæ vicinum habent mare, ut India, insulæ Indicæ, lingua Africæ, Guinea, Brasilia, Peruvia, Mexicana, Hispania: Pauca loca zonæ torridæ sunt mediterranea.*— "Most parts of the torrid zone are in the neighbourhood of the sea; as for example, India, the Indian islands, the peninsula of Africa, Guinea, Brasil, Peru, Mexico, Spain. Few parts of the torrid zone are inland."—*Varenii Geogr.* l. 2. c. 26. prop. 10. sect. 7.

plenty,

plenty, a ſurpluſage of this uſeful creature of God, (the freſh waters,) afforded to the world; and they ſo well ordered, as not to drown the nations of the earth, nor to ſtagnate, ſtink, and poiſon, or annoy them; but to be gently carried through convenient channels back again to their grand fountain (*f*), the

(*f*) That ſprings have their origin from the ſea, and not from rains and vapours, among many other ſtrong reaſons, I conclude from the perennity of divers ſprings, which always afford the ſame quantity of water. Of this ſort there are many to be found every where. But I ſhall, for an inſtance, ſingle out one in the pariſh of *Upminſter*, where I live, as being very proper for my purpoſe, and one that I have had better opportunities of making remarks upon above twenty years. This in the greateſt droughts is little, if at all diminiſhed, that I could perceive by my eye, although the ponds all over the country, and an adjoining brook, have been dry for many months together; as particularly in the dry ſummer months of the year 1705; and in the wetteſt ſeaſons, ſuch as the ſummer and other months were, preceding the violent ſtorm in *November* 1703. (Vide *Phil. Tranſ.* No. 289.) I ſay, in ſuch wet ſeaſons I have not obſerved any increment of its ſtream, excepting only for violent rains falling therein, or running down from the higher land into it; which diſcoloureth the waters oftentimes, and makes an increaſe of only a day's, or ſometimes but a few hours continuance. But now, if this ſpring had its origin from rain and vapours, there would be an increaſe and decreaſe of the one, as there ſhould happen to be of the other: As actually it is in ſuch temporary ſprings as have undoubtedly their ſource from rain and vapours.

But beſides this, another conſiderable thing in this *Upminſter* ſpring (and thouſands of others) is, that it breaks out of ſo inconſiderable an hillock, or eminence of ground, that can have no more influence in the condenſation of the vapours, or ſtopping the clouds, (which the maintainers of this hypotheſis ſuppoſe,) than the lower lands about it have. By ſome critical obſervations

the ſea; and many of them through ſuch large tracts of land, and to ſuch prodigious diſtances, that

ations I made with a very nice portable barometer, I found that my houſe ſtands between 80 and 90 feet higher than the low water mark in the river of *Thames*, neareſt me; and that part of the river being ſcarce 30 miles from the ſea, I gueſs, (and am more confirmed from ſome later experiments I made nearer the ſea,) that we cannot be much above 100 feet above the ſea. The ſpring I judge nearly level with or but little higher than where my houſe ſtands; and the lands from whence it immediately iſſues, I gueſs about 15 or 20 feet higher than the ſpring; and the lands above that, of no very remarkable height. And indeed, by actual meaſure, one of the higheſt hills I have met with in *Eſſex* is but 363 feet high (*Vid. Phil. Tranſ.* No. 313. p. 16.); and I gueſs by ſome very late experiments I made, neither that, nor any other land in *Eſſex*, to be above 400 feet above the ſea. Now what is ſo inconſiderable a riſe of land to a perennial condenſation of vapours, fit to maintain even ſo inconſiderable a fountain, as what I have mentioned is? Or indeed the high-lands of the whole large county of *Eſſex*, to the maintaining of all its fountains and rivulets?

But I ſhall no farther proſecute this argument, but refer to the late learned, curious, and induſtrious Dr. *Plot's Tentamen Phil. de Orig. Font.* in which he hath fully diſcuſſed this matter.

As to the manner how the waters are raiſed up into the mountains and higher lands, an eaſy and natural repreſentation may be made of it, by putting a little heap of ſand, aſhes, or a little loaf of bread, &c. in a baſon of water; where the ſand will repreſent the dry land, or an iſland, and the baſon of water the ſea about it. And as the water in the baſon riſeth to, or near the top of the heap in it, ſo do the waters of the ſea, lakes, &c. riſe in the hills. Which caſe I take to be the ſame with the aſcent of liquids in capillary tubes, or between contiguous planes, or in a tube filled with aſhes: of which the induſtrious and complete artificer in air-pumps, Mr. *Hawſkbee*, hath given us ſome, not contemptible experiments, in his *Phyſ. Mech. Exp.* p. 139.

Among

that it is a great wonder the fountains ſhould be high enough (*g*), or the ſeas low enough, ever to afford ſo long a conveyance. Witneſs the *Danube* (*h*) and *Wolga* of *Europe*, the *Nile* (*i*) and the *Niger* (*k*) of *Afric*, the *Ganges* (*l*) and *Euphrates* of *Aſia*, and the *Amazons river* (*m*) and *Rio de la Plata* of *America*,

Among the many cauſes aſſigned for this aſcent of liquors, there are two that bid the faireſt for it, *viz. the Preſſure of the Atmoſphere*, and the *Newtonian Attraction*. That it is not the former, appears from the experiments ſucceeding, as well, or better in *vacuo*, than in the open air, the aſcent being rather ſwifter in *vacuo*. This then being not the cauſe, I ſhall ſuppoſe the other is; but for the proof thereof, I ſhall refer to ſome of our late *Engliſh* authors, eſpecially ſome very late experiments made before our moſt famous *R. S.* which will be ſo well improved by ſome of that illuſtrious body, as to go near to put the matter out of doubt.

(*g*) See *Book* III. *Chap.* iv.

(*h*) *The* Danube, *in a ſober account, performs a courſe of above* 1500 *miles* (*i. e.* in a ſtrait line) *from its riſe to its fall.*—Bohun's Geogr. Dict.

(*i*) *Tractus* ſc. *Longitudo* [Nili] *eſt milliarium circiter* 630 *Germ. ſive Ital.* 2520, *pro quibus ponere licet* 3000 *propter curvaturas.*—" The courſe, that is to ſay the length, of the Nile, is about 630 German, or 2520 Italian miles; inſtead of which you may reckon 3000, on account of the windings of the river."—*Varen. Geogr.* l. 1. c. 16. p. 27.

(*k*) *Varene* reckons the courſe of the *Niger*, at a middle computation, 600 *German* miles, that is, 2400 *Italian.*

(*l*) That of the *Ganges* he computes at 300 *German* miles. But if we add the curvatures to theſe rivers, their channels are of a prodigious length.

(*m*) *Oritur, flumen (quod plerumque Amazonum, &c.) haud procul Quito in montibus.—Cùm per leucas Hiſpanicas* 1356, *curſum ab occidente in orientem continuàrit, oſtio* 84 *leucas lato—in oceanum præcipitatur.*—" The river of the Amazons, as it is commonly called, ariſes

rica, and many others which might be named; ſome of which are ſaid to run above 5000 miles, and ſome no leſs than 6000, from their fountains to the ſea. And indeed ſuch prodigious conveyances of the waters make it manifeſt, that no accidental currents and alterations of the waters themſelves, no art or power of man, nothing leſs than the *fiat* of the Almighty, could ever have made, or found, ſo long and commodious declivities, and channels for the paſſage of the waters.

ariſes in the mountains near to Quito. After continuing its courſe for 1356 Spaniſh leagues, from weſt to eaſt, it diſgorges itſelf into the ocean, by a mouth of 84 leagues in breadth."—*Chr. D'Acugna Relatio de flumine Amaz. in Act. Erud. Aug.* 1683.

CHAP. VI.

The great Variety and Quantity of all Things upon, and in the Terraqueous Globe, provided for the Uses of the World.

THE laſt remark I ſhall make about the Terraqueous Globe in general is, the great variety of kinds, or tribes *, as well as prodigious number of individuals of each various tribe, there is of all creatures (*a*). There are ſo many beaſts, ſo many

(*a*) *Non dat Deus beneficia? Unde ergò iſta quæ poſſides?—— Unde hæc innumerabilia, oculos, aures & animum mulcentia? Unde illa luxuriam quoque inſtruens copia? Neque enim neceſſitatibus tantummodò noſtris proviſum eſt: uſque in delicias amamur. Tot arbuſta, non uno modo frugifera, tot herbæ ſalutares, tot varietates ciborum, per totum annum digeſtæ, ut inerti quoque fortuita terræ alimenta præberent. Jam animalia omnis generis, alia in ſicco, &c. —ut omnis rerum naturæ pars tributum aliquod nobis conferret.—* "Does not God confer benefits? Whence then are thoſe that

* The invention of the microſcope has increaſed our knowledge of the variety of organized bodies in a moſt amazing degree. Mr. Adams, in his excellent treatiſe on that inſtrument, has in the following paragraph detailed the chief advantage we derive from it in the ſtudy of Nature: "The microſcope," ſays he, "extends the boundaries of the organs of viſion, enables us to examine the ſtructure of plants and animals; preſents to the eye myriads of beings of whoſe exiſtence we had before formed no idea; opens to the curious an inexhauſtleſs ſource of information and pleaſure; and furniſhes the philoſopher with an unlimited field of inveſtigation. It leads, to uſe the words of an ingenious writer, to the diſcovery of a thouſand wonders of *His* hand, who created

many birds, ſo many inſects, ſo many reptiles, ſo many trees, ſo many plants upon the land; ſo many

that thou poſſeſſeſt? Whence theſe innumerable objects ſo grateful to the eye, the ear, and the underſtanding? Whence thoſe ſupplies even of the moſt varied luxuries? For not only are our wants ſupplied; even our pleaſure and delight is provided for. So many fruitful ſhrubs, ſo many wholeſome herbs, ſuch variety of aliment provided for every ſeaſon; that the earth offers its fruits even to the indolent, who beſtow no care in its cultivation. Animals of all kinds, ſome belonging to the land, and others to the waters; ſo that every part of Nature ſeems to pay its tribute to man."—*Senec. de Benef.* l. 4. c. 5. *ubi plura vide.*

Hic, ubi habitamus non intermittit ſuo tempore cælum niteſcere, arbores frondeſcere—tum multitudinem pecudum partim ad veſcendum, partim ad cultus agrorum, partim ad vehendum, partim ad corpora veſtienda; hominemque ipſum quaſi contemplatorem cæli ac deorum, ipſorumque cultorem.—Hæc igitur, & alia innumerabilia cùm cernimus, poſſumuſne dubitare, quin his præſit aliquis vel effector, ſi hæc nata ſunt, ut Platoni videtur: vel ſi ſemper fuerint, ut Ariſtoteli placet, moderator tanti operis & muneris?—" In thoſe regions which we inhabit there is an invariable return of the vernal ſeaſon, and the renewal of vegetation.—Then, what a multitude of cattle, partly for food, and partly for the cultivation of the ground; ſome deſtined for burden, and others for ſupplying us with raiment.—And man too, whoſe intellect penetrates almoſt into the nature of the Gods whom he worſhips. —Can we then, while we ſurvey theſe, heſitate to pronounce, that if, according to Plato's opinion, they are produced at all, they

created ourſelves as well as the objects of our admiration; it improves the faculties, exalts the comprehenſion, and multiplies the inlets to happineſs, is a new ſource of praiſe to him to whom all we pay is nothing of what we owe; and while it pleaſes the imagination with the unbounded treaſures it offers to the view, it tends to make our whole life one continued act of admiration.

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many fifhes, fea-plants, and other creatures in the waters; fo many minerals, metals, and foffiles in the fubterraneous regions; fo many *fpecies* of thefe *genera*, fo many *individuals* of thofe *fpecies*, that there is nothing wanting to the ufe of man, or any other creature of this lower world. If every age doth change its food, its way of cloathing, its way of building; if every age (*b*) hath its variety of difeafes; nay, if man, or any other animal, was minded to change thefe things every day, ftill the creation would not be exhaufted, ftill nothing would be wanting for food, nothing for phyfick, nothing for building and habitation, nothing for cleanlinefs and refrefhment, yea, even for recreation and pleafure. But the munificence of the Creator is fuch, that there is abundantly enough to fupply the wants, the conveniencies, yea, almoft the extravagancies of all the creatures in all places, all ages, and upon all occafions.

they muft have been the effect of fome Almighty Caufe?—Or if, as Ariftotle thought, they have exifted from eternity, that there is a Sovereign Ruler and Difpofer of this great ftructure and arrangement of things?"—*Cic. Tufc. Quæft.* l. 1. c. 28, 29.

(*b*) *Sunt & gentium differentiæ non mediocres—quæ contemplatio aufert rurfus nos ad ipforum animalium naturas, ingenitafque iis vel certiores morborum omnium medicinas. Enim verò rerum omnium Parens, nullum animal ad hoc tantum ut pafceretur, aut alia fatiaret nafci voluit: artefque falutares iis inferuerit.*—"There is likewife a confiderable diverfity of the fpecies in different nations.—And this confideration leads us to remark the nature of animals, and the innate medicinal qualities which they poffefs, for the cure of all difeafes. For the univerfal Parent has not produced any animal for the fole purpofes of preferving its own exiftence, or fupplying food to others. He has given all animals certain medicinal virtues."—*Plin. Nat.Hift.* l. 27. c.13.

And

And this may ſerve to anſwer an objection againſt the excellency of, and wiſdom ſhewed in, the creation; namely, what need of ſo many creatures (*c*)? Particularly of ſo many inſects, ſo many plants, and ſo many other things? And eſpecially of ſome of them, that are ſo far from being uſeful, that they are very noxious; ſome by their ferity, and others by their poiſonous nature, &c.

To which I might anſwer, that in greater variety, the greater art is ſeen; that the fierce, poiſonous, and noxious creatures ſerve as rods and

(*c*) This was no very eaſy queſtion to be anſwered by ſuch as held, that *all things were made for man*; as moſt of the ancients did; as *Ariſtotle*, *Seneca*, *Cicero*, and *Pliny* (to name only ſome of the chief). And *Cicero* cites it as the celebrated *Chryſippus*'s opinion, *Præclarè enim Chryſippus, cætera nata eſſe hominum causâ, & deorum.*—"For Chryſippus rightly judged that all things were created for man and for the Gods."—*De fin. bon. & mal.* l. 3. And in his *De Nat. Deor.* l. 2. *fin.* he ſeriouſly proves the world itſelf to have been made for the Gods and man, and all things in the world to have been made and contrived for the benefit of man (*parata & inventa ad fructum hominum*, are his words). So *Pliny* in his preface to his 7th book ſaith, Nature made all things for man; but then he makes a doubt, whether ſhe ſhewed herſelf a more indulgent parent, or cruel ſtep-mother, as in *book* iv. *chap.* 12. *note* 2. But ſince the works of God have been more diſcovered, and the limits of the Univerſe have been found to be of infinitely greater extent than the ancients ſuppoſed them; this narrow opinion hath been exploded. And the anſwer will be found eaſy to theſe queſtions, Why ſo many uſeleſs creatures? In the Heavens, Why ſo many fix'd ſtars, and the greateſt part of them ſcarce viſible? Why ſuch ſyſtems of planets, as in *Jupiter*, *Saturn*, &c. (See my *Aſtro-Theology*.) In the earth and waters, Why ſo many creatures of no uſe to man?

ſcourges to chaſtiſe us (*d*), as means to excite our wiſdom, care, and induſtry, with more to the ſame

(*d*) *Nec minùs clara exitii documenta ſunt etiam ex contemnendis animalibus. M. Varro author eſt à cuniculis ſuſoſſum in Hiſpaniâ opidum, à talpis in Theſſaliâ: ab ranis civitatem in Galliâ pulſam, ab locuſtis in Africâ: ex Gyaro Cycladum inſulâ, incolas à muribus fugatos; in Italiâ Amyclas à ſerpentibus delatas. Citra Cynamolgos Æthiopas latè deſerta regio eſt, à ſcorpionibus & ſolpugis gente ſublatâ: & à ſcolopendris abactos Trerienſes, author eſt Theophraſtus.*—" And there are ſtrong proofs of the deſtructive powers of even the moſt contemptible animals. M. Varro tells us of a town in Spain that was undermined by rabbits, and of another in Theſſaly by moles; of a town in Gaul from which the inhabitants were driven out by frogs; of another in Africa, deſolated by locuſts. He relates how the inhabitants of Gyarus, one of the Cyclades, were expelled by mice, and that the Amyclæ in Italy were put to flight by ſerpents. Beyond the country of the Cynamolgi Ethiops, there is a wide extended region which is quite deſerted by its inhabitants on account of ſcorpions and venomous piſmires; and Theophraſtus informs us, that the inhabitants of Triers were driven out of their country by *ſcolopendræ*."—*Plin. Nat. Hiſt.* l. 8. c. 29.

To theſe inſtances may be added, the plague they ſometimes ſuffer from a kind of mice (they call *leming, leminger, lemmus*, &c.) in *Norway*, which eat up every green thing. They come in ſuch prodigious numbers, that they fancy them to fall from the clouds; but *Ol. Magnus* rather thinks they come from ſome of the iſlands, *Hiſt. l.* 8. *c.* 2 If the reader hath a mind to ſee a large account of them, with a diſpute about their generation, a handſome cut of them, with the prayers, and an exorciſm againſt them uſed in the church of *Rome*, I ſhall refer him (it being too tedious to recite in theſe Notes) to *Muſæum Wormian. l.* 3. *c.* 23.

Quare patimur multa mala à creaturâ quam fecit Deus, niſi quia offendimus Deum?—De pœnâ tuâ peccatum tuum accuſa, non judicem. Nam propter ſuperbiam inſtituit Deus creaturam iſtam minimam & abjectiſſimam, ut ipſa nos torqueret, ut cùm ſuperbus fuerit

ſame purpoſe. But theſe things have been fully urged by others; and it is ſufficient to ſay, that this

fuerit homo, & ſe jactaverit adverſus Deum,—cùm ſe erexerit, pulicibus ſubdatur. Quid eſt, quòd te inflas humanâ ſuperbiâ?—Pulicibus reſiſte, ut dormias. Cognoſce qui ſis. Nam propter ſuperbiam noſtram domandam—creata illa quæ moleſta ſunt; populum Pharaonis ſuperbum potuit Deus domare de urſis, de, &c. Muſcas & ranas illis immiſit, ut rebus viliſſimis ſuperbia domaretur. Omnia ergo per Ipſum——facta ſunt; & ſine Ipſo factum eſt nihil.— "Why do we ſuffer ſo many evils from God's creatures, unleſs becauſe we have offended God?—Blame thyſelf for thy puniſhment, and not thy Judge. For God, to puniſh our pride, has ſubjected us to ſuffer pain from the ſmalleſt and meaneſt inſect. Man who in his pride boaſts himſelf againſt his Maker, feels pain from the ſting of a flea. Why art thou ſo puffed up and elated? A flea ſhall deprive thee of ſleep.—Know better who thou art.—For even to quell that pride and arrogance of thine, thoſe offenſive inſects were perhaps called into exiſtence, God by means of bears, and of the nobler animals, might have ſubdued the haughty Egyptians. But he employed flies and frogs, that he might quell their pride, even by the meaneſt of his creatures.—All was created for Him, and without Him was nothing brought into Being."—*Auguſt. Tract.* 1. *in S. Johan.*

But although the infinitely wiſe Creator hath put it in the power of ſuch vile animals to chaſtiſe us, yet hath he ſhewed no leſs wiſdom and kindneſs in ordering many, if not moſt of them ſo, as that it ſhall be in the power of man, and other creatures, to obviate or eſcape their evils. For, beſides the noble antidotes afforded by minerals, vegetables, &c. many, if not moſt of our *European* venomous animals carry their cure, as well as poiſon, in their own bodies. The oil, and, I doubt not, the body of *ſcorpions* too, is a certain remedy againſt its ſtroke. A *bee*, *waſp*, or *hornet*, cruſhed and rubbed, and bound upon the place, I have always found to be a certain cure for the ſting of thoſe creatures. And I queſtion not, but the

this great variety is a most wise provision for all the uses of the world in all ages, and all places. Some for food, some for physic (*e*), some for habitation,

the flesh, especially the head, of *vipers*, would be found a remedy for their bites.

Our viper-catchers have a remedy, in which they place so great confidence, as to be no more afraid of the bite [of a viper] *than of a common puncture, immediately curing themselves by the application of their specific. This, though they keep a great secret, I have, upon strict enquiry, found to be no other than* Axungia Viperina, *presently rubbed into the wound.* This remedy the learned doctor tried himself with good success, in a young dog that was bitten in the nose. Vide *Mead of Poisons*, p. 29.

And as to the means to escape the mischief of such noxious animals, besides what may he effected by the care, industry, and sagacity of man; some of them are so contrived and made, as to give warning or time to creatures in danger from them. Thus, for instance, the *rattle-snake*, the most poisonous of any serpent, who darts its poisonous vapours to some distance, and in all probability was the *basilisk* of the antients, said to kill with its eyes, this involuntarily gives warning by the rattle in its tail. So the *shark*, the most rapacious animal of the waters, is forced to turn himself on his back (and thereby gives an opportunity of escape) before he can catch his prey.

(*e*) *Hæc sola Naturæ placuerat esse remedia parata vulgo, inventu facilia, ac sine impendio, ex quibus vivimus. Posteà fraudes hominum & ingeniorum capturæ officinas invenire istas, in quibus sua cuique homini venalis promittitur vita. Statim compositiones & misturæ inexplicabiles decantantur. Arabia atque India in medio æstimantur, ulcerique parvo medicina à Rubro mari imputatur, cùm remedia vera quotidie pauperrimus quisque cænet.*—" Nature knows no other medicines than what are easily supplied, without cost or labour, from the aliments on which we feed. The frauds, indeed, of man, and the artifices of ingenuity, have established those laboratories in which we are taught that life is to be bought for money. We are pestered with *nostrums* and inexplicable compositions. We must seek medicines from Arabia and

habitation, ſome for utenſils, ſome for tools and inſtruments of work, and ſome for recreation and pleaſure, either to man, or to ſome of the inferior creatures themſelves; even for which inferior creatures, the liberal Creator hath provided all things neceſſary, or anyways conducing to their happy, comfortable living in this world, as well as for man.

And it is manifeſt, that all the creatures of God, beaſts, birds, inſects, plants, and every other *genus*, have, or may have, their ſeveral uſes even among men *. For although in one place many

and from India; and for a trifling ſore, a remedy muſt be imported from the Red Sea, when the pooreſt peaſant has a better in thoſe ſimple aliments on which he daily feeds.—*Plin.* l. 24. c. 1.

Non ſponte ſuâ ex tellure germinant herbæ quæ contra quoſcunque morbos accommodatæ ſunt; ſed eæ voluntate opificis, ad noſtram utilitatem productæ ſunt.—"Thoſe herbs are not ſpontaneouſly brought forth by the earth which are accommodated to all diſeaſes; but human induſtry is requiſite towards their production.—*Baſil. Aſcet. tom.* 2.

Conſult here *book* x. *note* (*z*), (*aa*), (*bb*).

* "If it ſhould be objected," ſays Mr. Wollaſton, (Religion of Nature, ſect. 5.), "that many things ſeem to be uſeleſs, many births are monſtrous, or the like, ſuch anſwers as theſe may be made. The uſes of ſome things are known to ſome men and not to others; the uſes of ſome are known now that were not known to any formerly; the uſes of many may be known hereafter; and thoſe of ſome other things may for ever remain unknown to all men, and yet *be in Nature*, as much as thoſe diſcovered were before their diſcovery, or are now in reſpect of them who know them not."
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things

things may lie neglected, and out of ufe, yet in other places they may be of great ufe. So what hath feemed ufelefs in one age, hath been received in another; as all the new difcoveries in phyfic, and all the alterations in diet do fufficiently witnefs. Many things alfo there are which in one form may be pernicious to man; but in another of great ufe. There are many plants (*f*), many animals,

(*f*) Among poifonous vegetables, none more famous of old than *hemlock*, accounted at this day alfo very dangerous to man, of which there are fome difmal examples in our *Phil. Tranf. Wepfer*, &c. But yet this plant is food for *goats*, and its feeds to *buftards*; and as *Galen* faith, to *ftarlings* alfo. Neither is this fo pernicious a plant, only food, but alfo phyfic to fome animals. An horfe troubled with the *farcy*, and could not be cured with the moft famed remedies, cured himfelf of it in a fhort time, by eating *hemlock*, of which he eat greedily. Vide *Phil. Tranf.* No. 231. *And a woman which was cured of the plague, but wanted fleep, did with very good effect eat* hemlock *for fome time; till falling ill again of a fever, and having left off the ufe of this remedy, he* [Nic. Fontanus] *endeavoured to procure her reft by repeated dofes of* opium, *which had no operation, till the help of* cicuta *was again called in with defired fuccefs*. Mead. of Poif. *p.* 144 *.

And

* The *cicuta* is now very generally ufed in medicine. The experiments of Dr. Storck have fhewn it to be poffeffed of very powerful refolvent qualities in difeafes of a cancerous nature, and in fcrophula. It is commonly ufed in dofes of two or three grains of the powdered leaves a day; and fometimes an extract of the feeds of the plant is given with equal good effect.

Thus it may be referved for future ages to difcover medicinal ufes for all thofe vegetables which are at prefent known only for

animals, many minerals, which in one form deſtroy, in another heal. The *Caſſada plant* unprepared poiſoneth,

And not only *hemlock*, but many other, if not moſt plants accounted poiſonous, may have their great uſe in medicine: of which take the opinion of an able judge, my ingenious and learned

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for their noxious qualities. Even the dreadful *upas* or poiſon tree of the Iſland of Java, which is ſaid to depopulate the country for twelve or fourteen miles around the place of its growth, and create for itſelf a ſolitude where no living creature, nor even plant, except itſelf can exiſt, may, in after times, be found to be poſſeſſed of properties ſerviceable to man. The accounts given by naturaliſts of this tree are ſo extraordinary, that they have to many ſeemed a fiction of the imagination. We are informed, that Mr. Foerſch, a ſurgeon in the ſervice of the Dutch Eaſt India Company, ſtimulated by an eager curioſity to inveſtigate the truth of theſe accounts, procured a paſs from the Governor of Batavia, and travelled to the neareſt inhabited ſpot, which is about fifteen miles from the tree. Here an old prieſt reſides by appointment of the Emperor, whoſe office it is to prepare for eternity the ſouls of thoſe unhappy wretches who for their crimes are ſentenced to procure poiſon from the upas tree, an enterprize which not above one perſon out of ten, who attempt it, lives to accompliſh. The prieſt informed Mr. Foerſch, that he had diſpatched above 700 criminals on that expedition, and that the accounts of all who returned were perfectly correſpondent to each other. The tree is of a middling ſize, and ſtands on the border of a rivulet, having five or ſix young trees of the ſame ſpecies cloſe by it, but no other plant or ſhrub is ſeen, not even a blade of graſs, for many miles around. The ground is of a brown ſand, full of ſtones, and covered with dead bodies. It can only be approached with ſafety when the wind blows towards the tree, and the wind in that latitude is perpetually ſhifting. The perſon who arrives at the end of this hazardous journey, having his head and face covered

poisoneth, but prepared, is the very bread of the

learned friend Dr. *Tancred Robinson*, in a letter I have of his to the late great Mr. *Ray*, of *Nov.* 7, 1604, viz. *According to my promise, I here send you a few observations concerning some plants, seldom used in medicine, being esteemed poisonous, which if truly corrected, or exactly dosed, may perhaps prove the most powerful and effectual medicines yet known.* Having then given an account of some of their correctives, he gives these following examples, *viz.* 1. *The hellebores incorporated with a sapo, or alkaly-salts alone, are successful remedies in epilepsies, vertigos, palsies, lethargies, and manias. Dos.* a ℈ j. to ℥ ß. 2. *The Radic. Assari, Cicutæ, and the Napellus, in agues and periodical pains. Dos.* ℈ j. *to* ℥ ß. 3. *The hyoscyamus in hæmorrhagies, violent heats and perturbation of the blood, and also in all great inflammations. Dos.* ℈ j. *to* ℥ ß. 4. *The semen stramoniæ is a very good anodyne, useful in Vigilia's, rheumatisms, hysteric cases, in all the orgasms of the blood or spirits, and wherever there is an indication for a paregoric. Dos.* ℈ j. *to* ℥ ß. 5. *Elaterium thus corrected, may be given from gr.* x. *to* xv. *in hydropical cases, without any sensible evacuation or disturbance. So may the soldanella and gratiola in greater doses.* 6. *Opium corrected as afore-mentioned, loses its narcotick faculty, and may be given very safely in great doses, and proves more than usually prevalent in convulsive cases, fluxes, catarrhs, and all painful paroxysms,* &c.

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covered with a leather cap with glass eyes, hastily thrusts a few reeds obliquely into the bark of the tree, and draws them out filled at the end with its juice, which is of a resinous nature. The Malayans use it in poisoning arrows, and the wound is mortal in a few minutes. Mr. Foersch saw thirteen of the Emperor's concubines convicted of infidelity to his bed solemnly put to death by the wound of a poisoned lancet; they died in the greatest agonies within the space of sixteen minutes. *Botanic Garden* by *Darwin*, notes. This account, however, is discredited in Sir *George Staunton's Narrative of the Embassy to China.* 4to Edit. 1797. Vol. i. EDITOR.

West

West Indies (*g*). *Vipers* and *Scorpions*, and many minerals, as deftructive as they are to man, yet afford him fome of his beft medicines.

Or if there be many things of little, immediate ufe to man, in this, or any other age; yet to other creatures they may afford food or phyfic, or be of fome neceffary ufe. How many trees and planets, nay, even the very carcafes of animals, yea, the very duft of the earth (*h*), and the moft refufe, contemptible things to be met with; I fay, how many fuch things are either food, or probably medicine to many creatures, afford them retreat, are places of habitation, or matrixes for their generation, as fhall be fhewed in proper place? The prodigious fwarms of infects in the air, and in the waters, (many of which may be perhaps at prefent of no great ufe to man,) yet are food to birds, fifhes, reptiles, infects themfelves, and other creatures (*i*), for whofe happy and comfortable fubfiftence, I have faid the bountiful Creator

(*g*) *It is of the moft general ufe of any provifion all over the* Weft Indies, *efpecially in the hotter parts, and is ufed to victual fhips.* Dr. Sloan's Nat. Hift. of Jamaica, vol. 1. ch. 5. fect. 12.

(*h*) I have fhewn in the *Phil. Tranf.* that the *pediculus fatidicus, mortifaga, pulfatorius*, or *death-watch* there defcribed, feedeth upon duft; but that this duft they eat, is powdered bread, fruits, or fuch like duft, not powdered earth; as is manifeft from their great diligence and curiofity in hunting among the duft. See more in *Philof. Tranf.* No. 291.

(*i*) See *book* iv. *chap.* 11.

hath

hath liberally provided, as well as for that of man *.

* We ought not rafhly to conclude, that every fpecies of animals, apparently noxious to man, is in reality fo. A few years ago fome inhabitants of our American colonies endeavoured to extirpate the jack-daws becaufe they fancied that thofe birds did much mifchief to the corn; but in proportion as the number of jack-daws diminifhed, the people were ftruck with the havock made by an enormous multitude of worms, caterpillars, and particularly may-bugs. They foon ceafed to perfecute the jack-daws, and in proportion as thefe encreafed they found themfelves delivered of their plague of vermin. The author who relates this fact, with others of a fimilar nature, (Mr. Sturm,) draws the following juft conclufion: "Why fhould we be fo felfifh as to envy to animals the fmall part of our provifions which they require for food? Is it in our power to confume all that Nature produces? Shall we want any thing for our fupport or pleafure becaufe the birds, the mice, and the infects help us to make ufe of the bleffings which God grants in fuch profufion, and part of which would be wafted, were not the animals to feed upon it? Inftead of giving way to unjuft complaints, let us rather in this acknowledge the wifdom of our Creator. Every thing in Nature is connected together. No creature is ufelefs, or placed without defign, although the ufe of many animals is unknown to us. Thus the feeing the apparent deftruction and diforders in Nature ought to make us look up to a God who has created nothing in vain, who preferves nothing without a reafon; and who, if he permits any thing to be deftroyed, it is not without a wife defign. If we are thoroughly convinced of thefe truths, all the works of God will lead us to glorify and blefs him."

With regard to birds, "their ufes," fays Linnæus, "in the œconomy of Nature, and for the purpofes of mankind are various. The falcon tribe deftroy carcafes, which would otherwife become noifome; the order of pies, *picæ*, devour noxious fubftances

ſubſtances and worms; the anſerine tribe, *anſeres*, leſſen the too numerous inhabitants of the water; the waders, *grallæ*, ſeek for inſects and worms from bogs and marſhes; the gallinaceous tribe, *gallinæ*, pick up ſcattered ſeeds on the ground; the paſſerine tribe, *paſſeres*, feed on the ſeeds of ſhrubs and plants, and frequently carry theſe ſeeds, and the *ova*, or ſpawn of fiſhes and inſects, to places where they were not originally found, and thus help to diſſeminate uſeful productions."—*Ker's Tranſlation of Linnæus's Animal Kingdom.* EDITOR.

BOOK III.

Of the Terraqueous Globe in particular, more eſpecially the Earth.

HAVING thus taken a general proſpect of our Terraqueous Globe, I ſhall in this Book come to its particulars. But here we have ſuch an immenſe variety preſenting itſelf to our ſenſes, and ſuch amazing ſtrokes of power and wiſdom, that it is impoſſible not to be at a ſtand, and very difficult to know where to begin, how to proceed, or where to end. But we muſt, however, attempt.

And for the more clear and regular proceeding on this copious ſubject, I ſhall diſtribute the globe into its own grand conſtituent parts.

I. The *earth* and its appurtenances.

II. The *waters* and theirs.

The firſt of theſe only, is what at preſent I ſhall be able to take into this ſurvey.

And in ſurveying the *earth*, I intend,

1. To conſider its conſtituent parts, or things peculiar to itſelf.

2. The inhabitants thereof, or the ſeveral kinds of creatures that have their habitation, growth, or ſubſiſtence thereon.

1. As to the earth itſelf, the moſt remarkable things that preſent themſelves to our view, are,

1. Its various moulds and ſoils.

2. Its ſeveral ſtrata, or beds.

3. Its ſubterraneous paſſages, grottos, and caverns.

4. Its mountains and vallies.

CHAP. I.

Of the Soils and Moulds in the Earth.

THE various ſoils and moulds are an admirable and manifeſt contrivance of the all-wiſe Creator, in making this proviſion for the various vegetables (*a*), and divers other uſes of the creatures. For, as ſome trees, ſome plants, ſome grains dwindle and die in a diſagreeable ſoil, but thrive and flouriſh in others; ſo the all-wiſe

(*a*) It is not to be doubted, that although vegetables delight in peculiar ſoils, yet they owe not their life and growth to the earth itſelf, but to ſome agreeable juices or ſalts, *&c.* reſiding in the earth. Of this the great Mr. *Boyle* hath given us ſome good experiments. He ordered his gardener to dig up, and dry in an oven, ſome earth fit for the purpoſe, to weigh it, and to ſet therein ſome *ſquaſh ſeeds* (a kind of *Indian* pompion). The ſeeds when ſown were watered with rain or ſpring-water only. But although a plant was produced in one experiment of near 3 ℔, and in another of above 14 ℔, yet the earth when dried, and weighed again, was ſcarce diminiſhed at all in its weight.

Another experiment he alleges is of *Helmon*'s, who dried 200 ℔ of earth, and therein planted a willow weighing 5 ℔, which he watered with rain, or diſtilled water: and to ſecure it from any other earth getting in, he covered it with a perforated tin-cover. After five years, weighing the tree with all the leaves it had born in that time, he found it to weigh 169 lb. 3 ounces, but the earth to be diminiſhed only about 2 ounces in its weight. Vide *Boyle's Scept. Chym.* part. 2. p. 114.

 Creator

Creator hath amply provided for every kind a proper bed.

If ſome delight in a warm, ſome in a cold ſoil; ſome in a lax or ſandy, ſome a heavy or clayey ſoil; ſome in a mixture of both, ſome in this, and that, and the other mould, ſome in moiſt, ſome in dry places (*b*); ſtill we find proviſion enough for all theſe purpoſes *: Every country abounding

(*b*) Τοὺς δὲ τόπους ζητεῖ τοὺς οἰκείους, οὐ μόνον τὰ περιττὰ—Τῶν δένδρων, &c. Τὰ μὲν γὰρ φιλεῖ ξηροὺς, τὰ δὲ ἐνύδρους, τὰ δὲ χειμερινοὺς, τὰ δὲ προσήλους, τὰ δὲ παλισκίους, καὶ ὅλως, τὰ μὲν ὀρεινοὺς, τὰ δὲ ἑλώδεις.—Ζητεῖ γὰρ τὰ πρόσφορα κατὰ τὴν κρᾶσιν, ἔτι δὲ ἀσθενῆ, καὶ ἰσχυρὰ, καὶ βαθύῤῥιζα, καὶ ἐπιπολαιόῤῥιζα, καὶ εἴτις ἄλλη διαφορὰ κατὰ τὰ μέρη. Πάντα γὰρ ταῦτα, ἔτι δὲ τὰ ὅμοια ζητεῖ τὸ ὅμοιον, καὶ τὰ ἀνόμοια μὴ τὸν αὐτὸν, ὅταν ᾖ τις παραλλαγὴ τῆς φύσεως.—"All plants demand their proper places—for ſome love dry, and others moiſt ſituations; ſome a ſheltered or a ſhady receſs, and others a warm and open expoſure: ſome the mountainous, and ſome the marſhy. All ſeek that ſoil which is agreeable to their conſtitution; the weaker as well as the more hardy; thoſe that pierce deep with their roots, as well as thoſe that increaſe chiefly from the ſurface; in ſhort, wherever there is a difference in their parts or formation; for ſimilar plants require a ſimilar ſituation, and diſſimilar *vice verſa*, when there is any difference in their nature."—*Theophraſt. de Cauſ. Plant.* l. 2. c. 9.

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* The inhabitants of India, ſays Linnæus (Amæn. vol. v. p. 444.) ſuſtain an unceaſing languor from the heat of their climate, and are torpid in the midſt of profuſion. For this reaſon, the great Diſpoſer of Nature has clothed their country with trees of an amazing height, whoſe ſhade might defend them from the beams of the ſun, and whoſe continual freſhneſs might in ſome meaſure temperate their fierceneſs. From theſe

ing with its proper trees and plants (*c*), and every vegetable flouriſhing and gay, ſomewhere or other about the globe, and abundantly anſwering the almighty command of the Creator, when the earth and waters were ordered to their peculiar place, *Gen.* i. 11. *And God ſaid, Let the earth bring forth graſs, the herb yielding ſeed, and the tree yielding fruit after his kind.* All which we actually ſee is ſo.

(*c*) *Nec verò terræ ferre omnes omnia poſſunt.*
Fluminibus ſalices, craſſiſque paludibus alni
Naſcuntur; ſteriles ſaxoſis montibus orni:
Littora myrtetis lætiſſima: denique apertos
Bacchus amat colles: Aquilonem & frigora taxi.
Aſpice & extremis domitum cultoribus orbem,
Eoaſque domos Arabum, pictoſque Gelonos:
Diviſæ arboribus patriæ, &c. VIRG. Georg. *l.* 2.
" Nor every plant on every ſoil will grow;
The ſallow loves the watery ground and low;
The marſhes alders; Nature ſeems to ordain
The rocky cliff for the wild aſh's reign.
The baleful yew to northern blaſts aſſigns;
To ſhores the myrtles, and to mounts the vines.
Regard the extremeſt cultivated coaſt
From hot Arabia to the Scythian froſt;
All ſorts of trees their different countries know,
Black ebon only will in India grow,
And od'rous frankincenſe on the Sabæan bough.
DRYDEN's *Virgil.*

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theſe ſhades the air receives refreſhing moiſture, and animals a cooling protection. The whole race of ſavage animals retire in the midſt of the day to the centre of the foreſts, not ſo much to avoid their enemy man, as to find a defence againſt the raging heats of the ſeaſon. EDITOR.

To this convenience which the various ſoils that coat the earth are of to the vegetables, we may add their great uſe and benefit to divers animals, to many kinds of quadrupeds, fowls, inſects, and reptiles, who make in the earth their places of repoſe and reſt, their retreat in winter, their ſecurity from their enemies, and their neſts to repoſe their young; ſome delighting in a lax and pervious mould, admitting them an eaſy paſſage; and others delighting in a firmer and more ſolid earth, that will better ſecure them againſt injuries from without.

CHAP. II.

Of the various Strata, or Beds, obſervable in the Earth.

THE various *ſtrata*, or *beds*, although but little different from the laſt, yet will deſerve a diſtinct conſideration.

By the *ſtrata*, or *beds*, I mean thoſe layers of minerals (*a*), metals (*b*), earth and ſtone (*c*), lying under

(*a*) Although minerals, metals, and ſtones lie in beds, and have done ſo ever ſince *Noah*'s flood, if not from the creation; yet it is greatly probable that they have power of *growing* in their reſpective beds: that as the beds are robbed and emptied by miners, ſo after a while they recruit again. Thus *vitriol*, Mr. *Boyle* thinks, will grow by the help of the air. So *alum* doth the ſame. *We are aſſured* (he ſaith) *by the experienced* Agricola, *that the earth or ore of* alum, *being robbed of its ſalt, will in tract of time recover it, by being expoſed to the air.* Boyl. Suſpic. about ſome Hid. Qual. in the Air, *p.* 18.

(*b*) As to the growth of *metals*, there is great reaſon to ſuſpect that alſo, from what Mr. *Boyle* hath alleged in his *Obſervations about the Growth of Metals:* and in his *Scept. Chym.* part 6. p. 362. Compare alſo *Hakewil's Apol.* p. 164.

And particularly as to the growth of *iron*, to the inſtances he gives from *Pliny*, *Fallopius*, *Cæſalpinus*, and others; we may add, what is well known in the foreſt of *Dean* in *Glouceſterſhire:* That the beſt iron, and moſt in quantity, that is found there, is in the old cinders, which they melt over again. This the author of the *Additions to Glouceſterſhire in Cambden's Brit.* attributes to the remiſſneſs of the for-

under that upper *ſtratum*, or tegument of the earth laſt ſpoken of, all of a prodigious uſe to

mer melters, in not exhauſting the ore: but in all probability it is rather to be attributed to the new impregnations of the old ore, or cinders from the air, or from ſome ſeminal principle or plaſtick quality in the ore itſelf.

(*c*) As for the growth of *ſtone*, Mr. *Boyle* gives two inſtances. One is that famous place in *France*, called *Les Caves Goutieres*; *where the water falling from the upper parts of the cave to the ground doth preſently there condenſe into little ſtones, of ſuch figure as the drops, falling either ſeverally, or upon one another, and coagulating preſently into ſtones, chance to exhibit.* Nid. Scept. Chym. *p.* 360.

Such like caves as theſe I have myſelf met with in *England*; particularly on the very top of *Bredon-Hill* in *Worceſterſhire* near the *precipice*, facing *Perſhore*, in or near the old fortreſs called *Bemſbury-Camp*; I ſaw ſome years ago ſuch a cave, which (if I miſ-remember not) was lined with thoſe *ſtalactical ſtones* on the top and ſides. On the top they hung like icicles great and ſmall, and many lay on the ground. They ſeemed manifeſtly to be made by an exſudation, or exſtillation of ſome petrifying juices out of the rocky earth there. On the ſpot, I thought it might be from the rains ſoaking through, and carrying with it impregnations from the ſtone, the hill being there all rocky. Hard by the cave are one or more vaſt ſtones, which (if I miſtake not) are incruſtated with this ſparry, ſtalactical ſubſtance, if not wholly made of it. But it is ſo many years ago ſince I was at the place, and not being able to find my notes about it, I cannot ſay whether the whole ſtone is (in all probability) ſpar, (as I think it is,) or whether I found it only caſed over with it; notwithſtanding I was very nice in examining it then, and have now ſome of the fragments by me, conſiſting, among other ſhining parts, of ſome tranſparent angular ones.

The other inſtance of Mr. *Boyle*, is from *Linſchoten*, who ſaith, that in the *Eaſt Indies*, when they have cleared the diamond mines of all the diamonds, *in a few years time they find in the ſame place new diamonds produced.* Boyle, ibid.

mankind;

mankind; ſome being of great uſe for building; ſome ſerving for ornament; ſome furniſhing us with commodious machines, and tools to prepare our food, and for veſſels and utenſils, and for multitudes of other uſes; ſome ſerving for firing to dreſs our food, and to guard us againſt the inſults of cold and weather; ſome being of great uſe in phyſic, in exchange and commerce, in manuring and fertilizing our lands, in dying and colouring, and ten thouſand other conveniencies, too many to be particularly ſpoken of: only there is one grand uſe of one of theſe ſtrata or beds, that cannot eaſily be omitted, and that is, thoſe ſubterraneous ſtrata of ſand, gravel, and laxer earth that admit of, and facilitate the paſſage of the ſweet waters (*d*), and may probably be the colanders

(*d*) It is not only agreeable to reaſon, but I am told by perſons converſant in digging of wells throughout this county of *Eſſex*, where I live, that the ſureſt beds in which they find water, are *gravel*, and a coarſe dark-coloured *ſand*; which beds ſeldom fail to yield plenty of ſweet water: but for *clay*, they never find water therein, if it be a ſtrong ſtiff *clay*; but if it be lax and ſandy, ſometimes ſprings are found in it; yet ſo weak, that they will ſcarcely ſerve the uſes of the ſmalleſt family. And ſometimes they meet with thoſe beds lying next, under a looſe black mould, (which, by their deſcription, I judged to be a ſort of oozy, or to have the reſemblance of an ancient ruſhy ground,) and in that caſe the water is always naught, and ſtinks. And laſtly, another ſort of bed they find in *Eſſex*, in the clayey lands, particularly that part called the *Rodings*, which yields plenty of ſweet water, and that is a bed of white earth, as though made of chalk and white ſand. This

colanders whereby they are ſweetened, and then at the ſame time alſo conveyed to all parts of the habitable world, not only through the temperate and torrid zones, but even the fartheſt regions of the frozen poles.

That theſe ſtrata are the *principal paſſages* of the ſweet fountain-waters is, I think, not to be doubted, conſidering that in them the waters are well known to paſs, and in them the ſprings are found by thoſe that ſeek for them: I ſay, the principal paſſages, becauſe there are other ſubterraneous guts and channels, fiſſures and paſſages, through which many times the waters make their way.

Now that which in a particular manner doth ſeem to me to manifeſt a ſpecial Providence of God in the repoſiting theſe watery beds is, that they ſhould be diſperſed all the world over, into all countries, and almoſt all tracts of land: that they

This they find, after they have dug through forty or more feet of clay; and it is ſo tender and moiſt, that it will not lie upon the ſpade, but they are forced to throw it into their bucket with their hands, or with bowls; but when it comes up into the air, it ſoon becomes an hard white ſtone.

Thus much for the variety of beds wherein the waters are found. That it is in theſe beds only or chiefly the ſprings run, is farther manifeſt from the forcible eruption of the waters ſometimes out of thoſe watery beds. Of which ſee *chap.* 4. *note* (*k*). This eruption ſhews, that the waters come from ſome eminence or other, lying at a diſtance, and being cloſely pent upon within the *watery ſtratum*, by the clayey ſtrata, the waters with force mount up, when the ſtrata above are opened.

ſhould

ſhould ſo entirely, or for the moſt part, conſiſt of lax, incohering earth, and be ſo ſeldom blended with other impervious moulds, or if they are ſo, it is commonly but accidentally; and that they are interpoſed between the other impervious beds, and ſo are as a prop and pillar to guard them off, and to prevent their ſinking in and ſhutting up the paſſages of the waters.

The time when thoſe ſtrata were laid, was doubtleſs at the creation, when *God ſaid*, (Gen. i. 9.), *Let the waters under the Heaven be gathered together unto one place, and let the dry land appear;* or elſe at the deluge, if, with ſome ſagacious naturaliſts, we ſuppoſe the globe of earth to have been diſſolved by the flood (*e*). At that time (whatever it was) when the terraqueous globe was in a chaotic ſtate, and the earthy particles ſubſided, then thoſe ſeveral beds were in all probability repoſited in the earth, in that commodious order in which they now are found; and that, as is aſſerted, according to the laws (*f*) of gravity.

(*e*) Vide Dr. *Woodward's Eſſay*, part 2. *Steno's Prodr*, &c.

(*f*) *Id. ib.* p. 28, and 74. But Dr. *Leigh* in his *Nat. Hiſt. of Lancaſhire*, ſpeaking of the coal-pits, denies the ſtrata to lie according to the laws of gravitation, ſaying the ſtrata are a bed of *marle*, afterwards *free-ſtone*, next *iron-ſtone*, then *coal*, or *kennel-mine*, then ſome other ſtrata, and again *coal*, &c.

But upon a ſtricter enquiry into the matter, finding I had reaſon to ſuſpect that few, if any, actually had tried the experiment, I was minded to bring the thing to the teſt of experiment myſelf; and having an opportunity on *April* 11, 1712. I cauſed divers places to be bored, laying the ſeveral *ſtrata* by themſelves;

themſelves; which afterwards I weighed with all ſtrictneſs, firſt in air, then in water, taking care that no air bubbles, &c. might obſtruct the accuracy of the experiment. The reſult was, that in my yard, the ſtrata were gradually ſpecifically heavier and heavier, the lower and lower they went; and the upper which was clay, was conſiderably ſpecifically lighter than the lower *ſtratum*; which was firſt a looſe ſand, then a gravel. In which *ſtratum* principally the ſprings run that ſupply my well.

But in my fields, where three places were bored, (to no great depth,) I found below the upper (ſuperficial *ſtratum*) a deep bed of ſand only, which was of different colours and conſiſtence, which I weighed as before, together with the virgin-mould; but they were all of the ſame, or nearly the ſame ſpecific gravity, both out of the ſame hole, and out of different holes, although the ſand was at laſt ſo gravelly, that it hindered our boring any deeper.

Upon this, fearing leſt ſome error might be in the former experiments, I tried them over again; and that with the ſame ſucceſs.

After this I made ſome experiments in ſome deep chalk-pits, with the flints, chalk, &c. above and below; but the ſucceſs was not ſo uniform as before.

Acquainting our juſtly renowned *R. S.* with theſe experiments, they ordered their operator to experiment the *ſtrata* of a coal-pit; the ſucceſs whereof may be ſeen in *Philoſ. Tranſ.* No. 336.

CHAP. III.

Of the ſubterraneous Caverns, and the Volcano's.

I Shall take notice of the ſubterraneous caverns, grotto's, and volcano's, becauſe they are made an objection (*a*) againſt the preſent contrivance and ſtructure of the globe. But, if well conſidered, they will be found to be wiſe contrivances of the Creator, ſerving to great uſes of the globe, and ends of God's government. Beſides many ſecret grand functions and operations of Nature in the bowels of the earth, that in all probability theſe things may miniſter unto, they are of great uſe to the countries where they are (*b*). To inſtance in the

(*a*) *Nemo dixerit terram pulchriorem eſſe quòd cavernoſa ſit, quòd dehiſcat in multis locis, quòd diſrupta caveis & ſpatiis inanibus; iiſque nullo ordine diſpoſitis, nullâ formâ: nec quæ aliud contineant quàm tenebras & ſordes; unde graves & peſtiferæ exhalationes, terræ motus, &c.*—"Nobody will ſay, that the earth is the more beautiful, that it is full of cavities and fiſſures, and in many places abounds with large ſubterraneous empty ſpaces; and theſe too without order or ſymmetry, containing nothing but filth and darkneſs, often emitting dangerous and peſtiferous exhalations, and cauſing violent earthquakes, &c."—*Burnet ubi ſupr.* c. 7.

(*b*) The *Zirchnitzer* ſea in *Carniola* is of great uſe to the inhabitants of that country, by affording them fiſh, fowls, fodder, ſeeds, deer, ſwine, and other beaſts, carriage for their goods, &c. Vide *Phil. Tranſ.* No. 191, &c. or *Lowth. Abridg.*

the very worſt of the things named, *viz.* the *volcano's* and ignivomous mountains *, although they are ſome of the moſt terrible ſhocks of the globe, and dreadful ſcourges of the ſinful inhabitants thereof, and may ſerve them as emblems and preſages of hell itſelf; yet even theſe have their great uſes too, being as ſpiracles or tunnels (*c*) to the

Abridg. vol. ii. p. 306, &c. where you have put together in one view, what is diſperſed in divers of the *Tranſactions.* This ſea or lake proceeds from ſome ſubterraneous grotto, or lake, as is made highly probable by Mr. *Valvaſor. Ibid.*

The *grotto Podpetſchio* may be another inſtance, that the very ſubterraneous lakes may be of uſe, even to the inhabitants of the ſurface above: of which ſee *Lowth. ubi ſupr.* p. 317. *Sturmius* alſo may be conſulted here in his *Philoſ. Eclect. Exercit.* 11. *de Terræ mot.* particularly in *chap.* 3. ſome of the moſt eminent ſpecus's are enumerated, and ſome of their uſes.

(*c*) *Crebri ſpecus* [remedium] *præbent. Præconceptum enim ſpiritum exhalant: quod in certis notatur oppidis, quæ minùs quatiuntur,*

* There are at preſent no leſs than ſeventy-ſix volcanos in a ſtate of actual ignition; four in Europe, twenty-four in Aſia, three in Africa and in the iſlands that ſurround it, forty in America, and five in the iſlands of the Pacific Ocean. If the proximity of the ſea be neceſſary to ſupport the fire of volcanos, as is the prevailing opinion at preſent, according to the ſyſtem which attributes their inflammation to pyrites; we may doubt whether there be any more than thoſe above enumerated: for almoſt all the ſeas on the globe, with the coaſts which they waſh, have been carefully examined by very able naturaliſts, who could not have failed to obſerve them if there had been any. EDITOR.

the countries where they are, to vent the fire and vapours that would make difmal havoc, and oftentimes actually do fo, by dreadful fuccuffions and convulfions of the earth. Nay, if the hypothefis of a central fire and waters be true, thefe outlets feem to be of greateft ufe to the peace and quiet of the terraqueous globe, in venting the fubterraneous heat and vapours; which, if pent up, would make dreadful and dangerous commotions of the earth and waters.

It may be then accounted as a fpecial favour of the divine Providence, as is obferved by the author before praifed (*d*), " that there are fcarcely any " countries, that are much annoyed with earth- " quakes, that have not one of thefe fiery vents. " And thefe (faith he) are conftantly all in flames " whenever any earthquake happens, they difgorg- " ing that fire, which whilft underneath, was the " caufe of the difafter. Indeed, (faith he,) were " it not for thefe *diverticula*, whereby it thus gain- " eth an *exit*, it would rage in the bowels of the " earth much more furioufly, and make greater " havoc than now it doth. So, that though

untur, crebris ad eluviem cuniculis cavata.—" Thofe numerous cavities are of advantage; for they ferve to difcharge the vapours that are generated beneath the earth. Thus it has been obferved, that thofe places have been lefs fubject to earthquakes where the ground has been much excavated and interfected by common fewers."—*Plin. Hift. Nat.* l. 2. c. 82.

(*d*) *Woodward's Effay*, part 3. confect. 13.

" thofe

"those countries, where there are such *volcano's*, "are usually more or less troubled with earth-"quakes; yet, were these *volcano's* wanting, they "would be much more annoyed with them than "now they are; yea, in all probability to that "degree, as to render the earth, for a vast space "around them, perfectly uninhabitable. In one "word, (saith he,) so beneficial are these to the "territories where they are, that there do not "want instances of some which have been rescued, "and wholly delivered from earthquakes by the "breaking forth of a new *volcano* there; this con-"tinually discharging that matter, which being "till then barricaded up, and imprisoned in the "bowels of the earth, was the occasion of very "great and frequent calamities." Thus far that ingenious author *.

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* It is not foreign to the purpose of a work of the nature of the present, to take notice of an argument which of late has been urged against the authenticity of the Mosaic account of the creation, from the strata of volcanic lavas, which are found at a great depth in the earth; when we have it in our power at the same time to expose the insufficiency of the reasoning on which it is founded. It is observed by Sir William Hamilton and others, that in pits that have been dug in the vicinity of Vesuvius and Etna, many beds of lava have been discovered at considerable depths below each other, all of which are covered with successive strata of vegetable earth. These must have proceeded from successive eruptions, between each of which, a space of time must have intervened sufficient to convert the surface of the lava into vegetable mould; which space of time, estimating from

from the periods between the eruptions recorded in hiſtory, and the formation of ſoil that has been obſerved during thoſe periods, is computed at an average to have been 1000 years. Ten or twelve ſucceſſive ſtrata of lava, each covered with vegetable earth, are therefore proofs of a period of 10 or 12,000 years having elapſed ſince the firſt of thoſe eruptions.—This argument proceeds on aſſuming it as a fact that all lava is of the ſame nature, equally hard and ſolid, and capable of reſiſting equally the effects of the weather in converting its ſubſtance into mould. But this fact is contrary to truth, ſome lavas being incomparably more porous, friable, and eaſily diſſolved than others. Some eruptions are accompanied with vaſt ſhowers of aſhes, and conſiſt chiefly of ſuch; now a ſtratum of this nature will, in a very few years, acquire a ſurface fit for the purpoſes of vegetation, and ſuch, for any thing we know to the contrary, may have been the nature of moſt of thoſe numerous ſtrata, on which thoſe naturaliſts have founded their argument. Sir William Hamilton himſelf furniſhes a fact which, indeed, overturns the whole of this hypothetical reaſoning. The city of Herculaneum was deſtroyed by an eruption of Veſuvius, A. D. 97. There are evident marks, ſays he, that ſix eruptions of the mountain have taken their courſe over this city ſince it ſtood on the ſurface; for each of the ſix ſtrata of lava is covered with good vegetable ſoil. Now, theſe ſix vegetable coverings have been formed in leſs than 1700 years, which inſtead of giving 1000 years to the production of each, does not give even 300. —What then ſhall we ſay of a theory which reſts on ſo futile a foundation?

EDITOR.

CHAP. IV.

Of the Mountains and Valleys.*

THE laſt thing I ſhall take notice of relating to the earth, ſhall be the *hills* and *valleys*. Theſe the eloquent *theoriſt* owns to " contain ſomewhat " auguſt

* Mountains may be claſſed under four different heads: 1. Primitive; 2. Secondary, or regularly ſtratified; 3. Alluvial; 4. Volcanic. The primitive mountains are thoſe great bulwarks which form a chain on the ſurface of the earth, and greatly exceed the others in height. (See the phyſical map in *book* iv. c. 9. which gives a view of the great chains of primitive mountains, that interſect the continent of Europe, and part of Aſia and Africa.) They riſe often with a very ſudden elevation, and preſent aſtoniſhing peaks and precipices inacceſſible to the intrepidity of man, and have their ſummits covered with eternal ſnow, or accumulations of ice. Theſe great maſſes of matter are not ſtratified; they break into irregular ſhapes, and their component parts are of different ſizes, and irregularly mixed. They contain no petrifactions, and are therefore ſuppoſed to have exiſted previouſly to the formation of animals and vegetables.—The ſecondary mountains ſeem to be of a later formation: they have been produced by precipitation, and they conſiſt of ſtratified layers containing often petrifactions of animals and vegetables, and alſo metals.—The alluvial mountains have been apparently formed by depoſition at a later period than thoſe of the ſecond claſs. They are found on the beds of rivers, and near the ſea-coaſt; and they conſiſt of layers of calcareous and argillaceous earth, of loam

"august and stately in the beholding of them, that "inspireth the mind with great thoughts and passions, that we naturally on such occasions think "of God and his greatness." But then, at the same time, he saith, "The hills are the greatest "examples of ruin and confusion; that they have "neither form nor beauty, nor shape, nor order, "any more than the clouds in the air; that they "consist not of any proportion of parts, referable "to any design, nor have the least footsteps of "art or counsel." Consequently one grand part of this lower creation, even the whole present face of our terraqueous globe, according to this ingenious author, is a work of mere chance, a structure in which the Creator did not concern himself.

Part of this charge I have already briefly answered, and my survey now leads me to shew, that the mountains are so far from being a blunder of chance, a work without design, that they are a noble, useful, yea, a necessary part of our globe (*a*).

(*a*) *Though there are some that think mountains to be a deformity to the earth,* &c. *yet if well considered, they will be found as much to conduce to the beauty and conveniency of the universe, as any of the*

loam which consists of decomposed or mouldered stones, of sand and various other substances which the water has washed from the surface of the earth, or brought down from the higher mountains.—The volcanic mountains are formed by fire, and consist of basaltes, lavas, tufas, flags, pumices, ashes, &c. EDITOR.

And in the firſt place, as to the büſineſs of ornament, beauty, and pleaſure, I may appeal to all men's ſenſes, whether the grateful variety of hills and dales, be not more pleaſing than the largeſt continued plains. Let thoſe who make it their buſineſs to viſit the globe, to divert their ſight with the various proſpects of the earth; let thoſe, I ſay, judge whether the far diſtant parts of the earth would be ſo well worth viſiting, if the earth was every where of an even, level, globous ſurface, or one large plain of many 1000 miles; and not rather, as now it is, whether it be not far more pleaſing to the eye, to view from the tops of the mountains the ſubjacent vales and ſtreams, and the far diſtant hills; and again from the vales to behold the ſurrounding mountains. The elegant

the other parts. Nature (ſaith *Pliny*) *purpoſely framed them for many excellent uſes; partly to tame the violence of greater rivers, to ſtrengthen certain joints within the veins and bowels of the earth, to break the force of the ſea's inundation, and for the ſafety of the earth's inhabitants, whether beaſts or men. That they make much for the protection of beaſts, the Pſalmiſt teſtifies,* The higheſt hills are a refuge for the wild goats, and the rocks for conies. *The kingly prophet had likewiſe learnt the ſafety of thoſe by his own experience, when he alſo was fain to make a mountain his refuge from the fury of his maſter* Saul, *who proſecuted him in the wilderneſs. True indeed, ſuch places as theſe keep their neighbours poor, as being moſt barren, but yet they preſerve them ſafe, as being moſt ſtrong; witneſs our unconquered* Wales *and* Scotland.—*Wherefore a good author doth rightly call them* Nature's bulwarks, *caſt up at God Almighty's charges, the ſcorns and curbs of victorious armies; which made the* barbarians *in* Curtius *ſo confident of their own ſafety,* &c.—Biſhop Wilkin's World in the Moon, *p.* 114.

ſtrains and lofty flights, both of the ancient and modern poets on theſe occaſions, are teſtimonies of the ſenſe of mankind on this configuration of the earth.

But be the caſe as it will as to beauty, which is the leaſt valuable conſideration, we ſhall find as to convenience, this configuration of the earth to be far the moſt commodious on ſeveral accounts.

Firſt, As it is the moſt ſalubrious, of great uſe to the preſervation or reſtoration of the health of man. Some conſtitutions are indeed of ſo happy a ſtrength, and ſo confirmed an health, as to be indifferent to almoſt any place or temperature of the air: but then others are ſo weakly and feeble, as not to be able to bear one, but can live comfortably in another place. With ſome, the finer and more ſubtile air of the hills doth beſt agree, who are languiſhing and dying in the feculent and groſſer air of great towns, or even the warmer and vaporous air of the valleys and waters: but contrarywiſe others languiſh on the hills, and grow luſty and ſtrong in the warmer air of the valleys.

So that this opportunity of ſhifting our abode from the warmer and more vaporous air of the valleys, to the colder and more ſubtile air of the hills, or from the hills to the vales, is an admirable eaſement, refreſhment, and great benefit to the valetudinarian feeble part of mankind, affording thoſe an eaſy and comfortable life, who would otherwiſe live miſerably, languiſh, and pine away.

2. To this ſalutary conformation of the earth, we may add another great convenience of the hills, and that is, in affording commodious places for habitation: "Serving" (as an eminent author (*b*) wordeth it) "as ſkreens to keep off the cold and "nipping blaſts of the northern and eaſterly winds, "and reflecting the benign and cheriſhing ſun-"beams, and ſo rendering our habitations both "more comfortable and more chearly in winter; "and promoting the growth of herbs and fruit "trees, and the maturation of the fruits in ſum-"mer."

3. Another benefit of the hills is, that they ſerve for the production of great varieties of herbs and trees (*c*). And as there was not a better judge of thoſe matters, ſo I cannot give a better account of this convenience, than in the words of the laſt

(*b*) *Ray's Wiſdom of God*, &c. p. 251. *Diſſolution of the World*, p. 35.

(*c*) *Theophraſtus* having reckoned up the trees that delight moſt in the hills, and others in the valleys, obſerveth, 'Ἅπαντα δὲ ὅσα κοινὰ τῶν ὀρῶν καὶ τῶν πεδίων, μείζω μὲν καὶ καλλίω τῇ ὄψει τὰ ἐν τοῖς πεδίοις γίνεται. κρείττω δὲ τῇτε χρήσει τῶν ξύλων καί τῶν καρπῶν, τὰ ὀρεινά.' *Theoph. Hiſt. Pl.* l. 3. c. 4. Ἅπαντα δὲ ἐν τοῖς οἰκείοις τόποις καλλίω γίνεται, καὶ μᾶλλον εὐσθενεῖ.—Τα μὲν γὰρ φίλει τὰς ἐφύδρους καὶ ἑλώδεις.—Τὰ δὲ, τὰς εὐσκεπεῖς καὶ εὐηλίους. *Ibid.* l. 4. c. 1.—"But all thoſe which commonly grow both on the mountains and in the valleys are obſerved to thrive more luxuriantly in the valleys; but to produce better fruit, and to be more excellent in ſubſtance, when growing on the mountains; for all theſe plants grow beſt and moſt luxuriantly in their proper ſituations; for ſome prefer watery and marſhy ſoils, others an open and ſunny expoſure."

cited

cited famous author, the late moſt eminent and learned Mr. *Ray* (*d*), (who hath ſo fully diſcuſſed this ſubject I am upon, that it is ſcarce poſſible to tread out of his ſteps therein). His obſervation is, "That the mountains do eſpecially abound with "different ſpecies of vegetables, becauſe of the "great diverſity of ſoils that are found there, "every *vertex* or eminence almoſt affording new "kinds. Now theſe plants (ſaith he) ſerve part-"ly for the food and ſuſtenance of ſuch animals "as are proper to the mountains, partly for medi-"cinal uſes; the chief phyſic, herbs, and roots, "and the beſt in their kinds growing there: it be-"ing remarkable, that the greateſt and moſt lux-"uriant ſpecies in moſt genera of plants are native "of the mountains."

4. Another convenience which my laſt named learned friend obſerves (*e*) is, "that the moun-"tains ſerve for the harbour, entertainment, and "maintenance of various animals, birds, beaſts, "and inſects, that breed, feed, and frequent there. "For (ſaith he) the higheſt tops and pikes of "the *Alpes* themſelves are not deſtitute of their in-"habitants, the *ibex* or *ſtein-buck*, the *rupicapra* "or *chamois*, among quadrupeds; the *lagopus* "among birds. And I myſelf (ſaith he) have ob-"ſerved beautiful *papilio*'s, and ſtore of other in-"ſects upon the tops of ſome of the *Alpine* moun-

(*d*) *Wiſdom of God*, p. 252. (*e*) *Ubi ſupra.*

"tains. Nay, the higheſt ridges of many of theſe "mountains ſerve for the maintenance of cattle, "for the ſervice of the inhabitants of the valleys."

5. Another thing he obſerves is, "that thoſe "long ridges and chains of lofty and topping "mountains, which run through whole continents "Eaſt and Weſt (*f*), ſerve to ſtop the evagation of "the vapours to the North and South in hot coun- "tries, condenſing them like alembic heads into "water, and ſo (according to his opinion) by a "kind of external diſtillation giving original to "ſprings and rivers; and likewiſe by amaſſing, "cooling, and conſtipating of them, turn them into "rain, by thoſe means rendering the fervid re- "gions of the torrid-zone habitable."

To theſe might be added ſome other uſes and conveniencies (*g*); as that the hills ſerve to the genera-

(*f*) Many have taken notice, that ſome of the greateſt eminences of the world run generally Eaſt and Weſt, of which take the late ingenious and learned Dr. *Nichols*'s account [*Confer. with a Theiſt*, part ii. p. 191.] *To go no farther than our own country, all our great ridges of hills in* England *run Eaſt and Weſt*; *ſo do the* Alps *in* Italy, *and in ſome meaſure the* Pyrenees; *ſo do the mountains of the moon in* Africk, *and ſo do* Mount Taurus *and* Caucaſus. *This* (he ſaith) *is a wiſe contrivance to prevent the vapours, which would all run northwards, and leave no rains in the* Mediterranean *countries.*

(*g*) That the generation of many of the clouds is owing to the hills, appears from the obſervations of the ingenious and learned Dr. *Joh. Jam. Scheuchzer* of *Zurich*, and Mr. *Joach. Frid. Creitlovius* cited by him. They obſerved at ſun-riſing,

generation of minerals and metals (*h*), and that in them principally are the moſt uſeful foſſiles found;

riſing, divers clouds detached by the heat of the ſun, from ſome of the tops of the *Alps*, &c. upon all which their obſervations, the concluſion is, *Mirati ſummam Creatoris ſapientiam, qui & id quod paulò antè nulli nobis uſui eſſe videbatur, maximis rebus deſtinaverat, adeòque ex illo tempore dubitare cœpi, num nubes eſſent futuræ, ſi iſtiuſmodi montes & petræ non darentur. Hypotheſi hâc ſtante, eluceſceret permagna utilitas, imò neceſſitas, quam* Helveticæ Alpes *non nobis tantùm accolis ſed & vicinis aliis regionibus præſtant, diſpenſando, quas gignunt nubes, ventos, aquas.*—"We admired the great wiſdom of the Creator, who had deſtined for the moſt important purpoſes thoſe things which before ſeemed to us of no utility; and I then began to doubt, whether thoſe clouds would ariſe, if it were not for the mountains and rocks. If this hypotheſis is juſt, it will thence appear how uſeful, how neceſſary thoſe Helvetic Alps are to us, as well as to the neighbouring regions, in generating clouds, winds, and rain."—*Scheuch. Iter. Alpin.* 2. p. 20.

(*h*) Let us take here *Ol. Mag.* Obſervation on his Northern Mountains: *Montes excelſi ſunt, ſed pro majori parte ſteriles, & aridi; in quibus ferè nil aliud pro incolarum commoditate & conſervatione gignitur, quàm inexhauſta pretioſorum metallorum ubertas, quâ ſatis opulenti, fertileſque ſunt in omnibus vitæ neceſſariis, forſitan & ſuperfluis àliunde ſi libet conquirendis, unanimique robore, ac viribus, ubi vis contra hæc naturæ dona intentata fuerit, defendendis. Acre enim genus hominum eſt, &c.*—"The mountains are high, but for the moſt part dry and barren, producing nothing for the ſupport or utility of the inhabitants, but an inexhauſtible ſtore of the moſt precious metals, by which they are ſupplied, even to opulence, with all the neceſſaries and even the ſuperfluities of life, which they purchaſe from other quarters. The nature of their country too, gives that ſtrength and vigour of conſtitution to its inhabitants, which enables them to defend thoſe gifts of Nature againſt all invaders. They are a moſt hardy race of men."—*Ol. Mag. Hiſt.* l. 6. Præf. See alſo Sir *Robert Sibbald's Prodr. Nat. Hiſt. Scot.* p. 47.

or if not found and generated only in them, yet at leaſt all theſe ſubterraneous treaſures are moſt eaſily come at in them: alſo their uſe to ſeveral nations of the earth, in being boundaries and bulwarks to them. But there is only one uſe more that I ſhall inſiſt on, and that is,

6. And laſtly, that it is to the hills that the fountains owe their riſe, and the rivers their conveyance. As it is not proper, ſo neither ſhall I here enter into any diſpute about the origin of ſprings, commonly aſſigned by curious and learned philoſophers. But whether their origin be from condenſed vapours, as ſome think (*i*); or from rains falling, as others; or whether they are derived from the ſea by way of attraction, percolation, or diſtillation; or whether all theſe cauſes concur, or only ſome, ſtill the hills are the grand agent in this prodigious benefit to all the earth: thoſe vaſt maſſes and ridges of earth ſerving as ſo many huge *alembics* or *cola* in this noble work of Nature.

But be the *modus*, or the method Nature takes in this great work as it will, it is ſufficient to my purpoſe, that the hills are a grand agent in this ſo noble and neceſſary a work: and conſequently, that thoſe vaſt maſſes, and lofty piles, are not as they are charged, ſuch rude and uſeleſs excreſcences of our ill-formed globe; but the admirable tools of Nature, contrived and ordered by the infinite

(*i*) See *book* i. *chap.* iii. *note* (*b*).

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finite Creator, to do one of its moſt uſeful works, and to diſpenſe this great bleſſing to all parts of the earth; without which neither animals could live, nor vegetables ſcarcely grow, nor perhaps minerals, metals, or foſſiles receive any increaſe. For was the ſurface of the earth even and level, and the middle parts of its iſlands and continents not mountainous and high, (as now it is,) it is moſt certain there could be no deſcent for the rivers, no conveyance for the waters; but inſtead of gliding along thoſe gentle declivities which the higher lands now afford them quite down to the ſea, they would ſtagnate, and perhaps ſtink, and alſo drown large tracts of land.

But indeed, without hills, as there could be no rivers, ſo neither could there be any fountains, or ſprings about the earth; becauſe, if we could ſuppoſe a land could be well watered (which I think not poſſible) without the higher lands, the waters could find no deſcent, no paſſage through any commodious outlets, by virtue of their own gravity; and therefore could not break out into thoſe commodious paſſages and currents, which we every where almoſt find in or near the hills, and ſeldom or never in large and ſpacious plains; and when we do find them in them, it is generally at great and inconvenient depths of the earth; nay, thoſe very ſubterraneous waters, that are any where met with by digging in theſe plains, are in all probability owing to the hills, either near or far diſtant: as among other inſtances may be made

out,

out, from the forcible eruption of the ſubterraneous waters in digging wells in the *Lower Auſtria*, and the territories of *Modena*, and *Bologna* in *Italy*, mentioned by my fore-named learned friend Mr. *Ray* (*k*). Or if there be any ſuch place found throughout the earth, that is devoid of mountains, and yet well watered, as perhaps ſome ſmall iſlands may; yet in this very caſe, that whole maſs of land is no other than as one mountain

(*k*) *Monſieur* Blundel, *related to the* Pariſian *academy*, *what device the inhabitants of the* Lower Auſtria (*which is encompaſſed with the mountains of* Stiria) *are wont to uſe to fill their wells with water. They dig in the earth to the depth of twenty-five and twenty feet, till they come to an argilla* [clammy earth] ——*which they bore through ſo deep, till the waters break forcibly out; which water it is probable comes from the neighbouring mountains in ſubterraneous channels. And* Caſſinus *obſerved, that in many places of the territory of* Modena *and* Bologna *in* Italy, *they make themſelves wells by the like artifice*, &c. *By this means the ſame* Seig-Caſſini *made a fountain at the caſtle of* Urbin, *that caſt up the water five foot high above the level of the ground.*—Ray's Diſc. 1. p. 40. ubi plura.

Upon inquiry of ſome ſkilful workmen, whoſe buſineſs it is to dig wells, *&c.* whether they had ever met with the like caſe, as theſe in this note, they told me they had met with it in *Eſſex*, where, after they had dug to fifty foot depth, the man in the well obſerved the clayey bottom to ſwell and begin to ſend out water, and ſtamping with his foot to ſtop the water, he made way for ſo ſudden and forcible a flux of water, that before he could get into his bucket, he was above his waſte in water; which ſoon aſcended to ſeventeen feet height, and there ſtayed: and although they often, with great labour, endeavoured to empty the well, in order to finiſh their work, yet they could never do it, but were forced to leave it as it was.

defcending (though unperceivedly) gently down from the midland parts to the fea, as moft other lands do; as is manifeft from the defcent of their rivers, the principal of which in moft countries have generally their rife in the more lofty midland parts.

And now confidering what hath been faid concerning this laft ufe of the hills, there are two or three acts of the Divine Providence obfervable therein. One is, that all countries throughout the whole world fhould enjoy this great benefit of mountains, placed here and there, at due and proper diftances, to afford thefe feveral nations this excellent and moft neceffary element the waters. For according to Nature's tendency, when the earth and waters were feparated, and ordered to their feveral places, the earth muft have been of an even furface, or nearly fo. The feveral component parts of the earth muft have fubfided according to their feveral fpecific gravities, and at laft have ended in a large, even, fpherical furface, every where equi-diftant from the centre of the globe. But that inftead of this form, fo incommodious for the conveyance of the waters, it fhould be jetted out every where into hills and dales, fo neceffary for that purpofe, is a manifeft fign of an efpecial Providence of the wife Creator.

So another plain fign of the fame efpecial Providence of God, in this matter, is, that generally, throughout the whole world, the earth is fo difpofed, fo ordered, fo well-laid; I may fay, that the

midland

midland parts, or parts fartheſt from the ſea, are commonly the higheſt: which is manifeſt, I have ſaid, from the deſcent of the rivers. Now this is an admirable proviſion the wiſe Creator hath made for the commodious paſſages of the rivers, and for draining the ſeveral countries, and carrying off the ſuperfluous waters from the whole earth, which would be as great an annoyance, as now they are a convenience.

Another providential benefit of the hills ſupplying the earth with water, is, that they are not only inſtrumental thereby, to the fertility of the valleys, but to their own alſo (*l*); to the verdure of the vegetables without, and to the increment and vigour of the treaſures within them.

Thus having vindicated the preſent form and fabric of the earth, as diſtributed into mountains

(*l*) As the hills being higher, are naturally diſpoſed to be drier than the valleys; ſo kind Nature hath provided the greater ſupplies of moiſture for them, ſuch at leaſt of them as do not aſcend above the clouds and vapours. For, beſides the fountains continually watering them, they have more dews and rains commonly than the valleys. They are more frequently covered with fogs; and by retarding, ſtopping, or compreſſing the clouds, or by their greater colds condenſing them, they have larger quantities of rain fall upon them: as I have found by actual experience, in comparing my obſervations with thoſe of my late very curious and ingenious correſpondent, *Richard Townley*, eſq. of *Lancaſhire*, and ſome others, to be met with before, *chap.* ii. *note* (*a*). From which it appears, that above double the quantity of rain falleth in *Lancaſhire*, than doth at *Upminſter*. The reaſon of which is, becauſe *Lancaſhire* hath more, and much higher hills than *Eſſex* hath. See *book* ii. *chap.* 5. *note* (*e*).

and

and valleys, and thereby ſhewn in ſome meaſure the uſe thereof, particularly of the mountains, which are chiefly found fault with; I have, I hope, made it in ſome meaſure evident, that God was no idle ſpectator (*m*), nor unconcerned in the ordering of the terraqueous globe, as the former bold charges againſt it do infer; that he did not ſuffer ſo grand a work as the earth to go unfiniſhed out of his Almighty Hand; or leave it to be ordered by chance, by natural gravity, by caſual earthquakes, *&c.* but that the noble ſtrokes, and plain remains of wiſdom and power therein, do manifeſt it to be his work. That particularly the hills and vales, though to a peeviſh weary traveller they may ſeem incommodious and troubleſome, yet are a noble work of the great Creator, and wiſely appointed by him for the good of our ſublunary world.

And ſo for all the other parts of our terraqueous globe, that are preſumed to be found fault with by ſome, as if careleſsly ordered, and made without any deſign or end; particularly the diſtribution of the dry land and waters; the laying the ſeveral ſtrata, or beds of earth, ſtone, and

(*m*) *Accuſandi ſanè meâ ſententiâ hic ſunt ſophiſtæ, qui cùm nondum invenire, neque exponere opera Naturæ queant, eam tamen inertiæ atque inſcitiæ condemnant*, &c.—" Thoſe ſophiſts are, in my opinion, truly blamable, who, unable to inveſtigate or to explain the operations of Nature, yet pretend to accuſe her of ignorance and unſkilfulneſs."—*Galen. de Uſ.* part i. l. 10. c. 9.

other

other layers before ſpoken of; the creation of noxious animals, and poiſonous ſubſtances; the boiſterous winds; the volcano's, and many other things which ſome are angry with, and will pretend to amend: I have before ſhewn, that an infinitely wiſe Providence, an Almighty Hand was concerned even in them; that they all have their admirable ends and uſes, and are highly inſtrumental and beneficial to the being, or well-being of this our globe, or to the creatures reſiding thereon.

So alſo for human bodies, it hath been an ancient (*n*), as well as modern complaint, that our bodies

(*n*) *Vide quàm iniqui ſint divinorum munerum æſtimatores, etiam quidam profeſſi ſapientiam. Querantur quòd non magnitudine corporum æquemus elephantes, velocitate cervos, levitate aves, impetu tauros; quòd ſolidior ſit cutis belluis, decentior damis, denſior urſis, mollior fibris; quòd ſagacitate nos narium canes vincant, quòd acie luminum aquilæ, ſpatio ætatis corvi, multa animalia nandi facilitate. Et cùm quædam nè coire quidem in idem Natura patiatur, ut velocitatem corporis & vires pares animalibus habeamus; ex diverſis & diſſidentibus bonis hominem non eſſe compoſitum, injuriam vocant; & in negligentes noſtri Deos querimoniam jaciunt, quòd non bona valetudo, & vitiis inexpugnabilis data ſit, quòd non futuri ſcientia. Vix ſibi temperant quin eouſque impudentiæ provehantur, ut Naturam oderint, quòd infra Deos ſumus, quòd non in æquo illis ſtetimus.*—" Mark how unjuſtly the Divine Bounty is eſtimated even by thoſe who pretend to be philoſophers. They complain that man does not equal the elephant in bulk, the ſtag in velocity, the birds in lightneſs, the bull in ſtrength; they complain that Nature ſhould have given a ſtronger ſkin to the wild beaſts than to them; a finer covering to the doe, a thicker to the bear, a ſofter to the beaver: that the dogs ſurpaſs us in acuteneſs of ſmell, the

bodies are not as big as thoſe of other animals; that we cannot run as ſwift as deer, fly like birds, and that we are out-done by many creatures in the accuracy of the ſenſes, with more to the ſame purpoſe. But theſe objections are well anſwered by *Seneca* (*o*), and will receive a fuller ſolution from what I ſhall obſerve of animal bodies hereafter.

But indeed, after all, it is only for want of our knowing theſe things better, that we do not ad-

the eagles in ſight, the ravens in longevity, and a variety of animals in the faculty of ſwimming. And even in thoſe particulars which Nature has refuſed to combine, ſuch as the greateſt ſtrength and the greateſt velocity, they think they are unjuſtly dealt with, if for their ſake the moſt diſcordant qualities are not united: they accuſe the Gods, that human Nature is ſubject to infirmity and diſeaſe; they repine that they have not a knowledge of futurity. Scarcely do they refrain from curſing Nature for not forming them equal to the Divinity."—*Seneca de Benef.* lib. 2. c. 29.

(*o*) *Quanto ſatiùs eſt ad contemplationem tot tantorumque beneficiorum reverti, & agere gratias, quòd nos in hoc pulcherrimo domicilio voluerunt* (Dii) *ſecundos ſortiri, quòd terrenis præfecerunt.*—"How much better is it to turn to the contemplation of ſuch various, ſuch extenſive bleſſings, and to render thanks to the Divinity for having placed us inferior only to himſelf in this beautiful manſion; for having ſet us above all other earthly creatures."—Then having reckoned up many of the privileges and benefits, which the Gods, he ſaith, have conferred upon us, he concludes, *Ita eſt: cariſſimos nos habuerunt Dii immortales, habentque. Et qui maximus tribui honos potuit, ab ipſis proximos collocaverunt. Magna accepimus, majora non cepimus.*—"For ſo it is: we are moſt dear in the ſight of the Gods, and always have been ſo: for (what is our higheſt honour) they have ranked us next to themſelves."—*Senec. Ibid.*

mire (*p*) them enough; it is our own ignorance, dulneſs, or prejudice, that makes us charge thoſe noble works of the Almighty, as defects or blunders, as ill-contrived, or ill made.

It is therefore fitter for ſuch finite, weak, ignorant beings as we, to be humble and meek, and conſcious of our ignorance, and jealous of our own judgment, when it thus confronteth infinite wiſdom. Let us remember how few things we know, how many we err about, and how many we are ignorant of: and thoſe, many of them, the moſt familiar, obvious things; things that we ſee and handle at pleaſure; yea, our own very bodies, and that very part of us whereby we underſtand at all, our ſoul. And ſhould we therefore pretend to cenſure what God doth! Should we pretend to amend his work! or to adviſe infinite wiſdom! or to know the ends and purpoſes of his infinite will, as if we were of his council! No, let us bear in mind, that theſe objections are the products, not of reaſon, but of peeviſhneſs. They have been incommoded by ſtorms and tempeſts; they have been terrified with the burning mountains, and earthquakes; they have been annoyed by the noxious animals, and fatigued by the hills; and therefore are angry, and will pretend to amend theſe works of the Almighty. But in the words of St. Paul,

(*p*) *Naturam maximè admiraberis, ſi omnia ejus opera perluſtrâris.*—"Could you ſurvey all the works of Nature, great would be your admiration."—*Galen. de Uſ. Part.* l. 11. concluſ.

Paul (*q*), we may ſay, *Nay, but O man, who art thou that replieſt againſt God? Shall the thing formed ſay to him that formed it, Why haſt thou made me thus? Hath not the potter power over the clay, of the ſame lump, to make one veſſel to honour, and another to diſhonour?* If the Almighty Lord of the world had, for his own pleaſure, made this our world more inconvenient for man, it would better become us to ſit ſtill, and be quiet; to lament our own great infirmities and failings, which deſerve a worſe place, a more incommodious habitation, than we meet with in this elegant, this well-contrived, well-formed world; in which we find every thing neceſſary for the ſuſtentation, uſe, and pleaſure, both of man, and every other creature here below; as well as ſome whips, ſome rods to ſcourge us for our ſins (*r*). But yet ſo admirably well tempered is our ſtate, ſuch an accord,

(*q*) *Rom.* ix. 20, 21.

(*r*) *Neither are they* [noxious creatures] *of leſs uſe to amend our minds, by teaching us care and diligence, and more wit. And ſo much the more, the worſe the things are we ſee, and ſhould avoid.* Weazels, kites, *and other miſchievous animals, induce us to a watchfulneſs:* thiſtles *and* moles *to good huſbandry;* lice *oblige us to cleanlineſs in our bodies;* ſpiders *in our houſes; and the* moth *in our clothes. The deformity and filthineſs of* ſwine, *make them the beauty-ſpot of the animal-creation, and the emblems of all vice.—The truth is, things are hurtful to us only by accident; that is, not of neceſſity, but through our own negligence or miſtake. Houſes decay, corn is blaſted, and the weazel breeds in malt, ſooneſt towards the South. Be it ſo, it is then our own fault, if we uſe not the means which Nature and art have provided againſt theſe inconveniences.*—Grew's Coſmol. *c.* 2. *ſect.* 49, 50.

ſuch an harmony is there throughout the creation, that if we will but purſue the ways of piety and virtue, which God hath appointed; if we will form our lives according to the Creator's laws, we may eſcape the evils of this our frail ſtate, and find ſufficient means to make us happy whilſt we are in the body. The natural force and tendency of our virtue, will prevent many of the harms (*ſ*), and the watchful Providence of our Almighty Benefactor will be a guard againſt others; and then nothing is wanting to make us happy, as long as we are in this world, there being abundantly enough to entertain the minds of the moſt contemplative; glories enough to pleaſe the eye of the moſt curious and inquiſitive; harmonies and conſorts of Nature's own, as well as man's making, ſufficient to delight the ear of the moſt harmonious and muſical; all ſorts of pleaſant guſto's to gratify the taſte and appetite, even of the moſt luxurious; and fragrant odours to pleaſe the niceſt and tendereſt ſmell: and in a word, enough to make us love and delight in this world, rather too much than too little, conſidering how nearly we are allied to another world, as well as this.

(*ſ*) *Nunquam Stygias fertur ad umbras*
Inclyta virtus. Senec. Her. Oet. Act 5. Car. 1982.
" True virtue muſt eſcape the Stygian ſhades."

BOOK IV.

Of Animals in general.

IN the laſt Book, having ſurveyed the earth itſelf in particular, I ſhall next take a view of the inhabitants thereof; or the ſeveral kinds of creatures (*a*), that have their habitation, growth, or ſubſiſtence thereon.

(*a*) *Principio cœlum, ac terras, campoſque liquentes,*
Lucentemque globum Lunæ, Titaniaque aſtra
Spiritus intùs alit, totamque infuſa per artus
Mens agitat molem, & magno ſe corpore miſcet.
Inde hominum, pecudumque genus, vitæque volantum,
Et quæ marmoreo fert monſtra ſub æquore pontus,
Igneus eſt ollis vigor, & cœleſtis origo
Seminibus. VIRG. Æneid. *l.* 6. *carm.* 724.

" Know firſt that heaven and earth's compacted frame,
And flowing waters, and the ſtarry flame,
And both the radiant lights, one common ſoul
Inſpires and feeds, and animates the whole.
This active mind infus'd through all the ſpace,
Unites, and mingles with the mighty maſs.
Hence men and beaſts the breath of life obtain,
And birds of air, and monſters of the main.
Th' etherial vigour is in all the ſame,
And ev'ry ſoul is fill'd with equal flame."

DRYDEN's Virgil.

Theſe creatures are either ſenſitive, or inſenſitive creatures.

In ſpeaking of thoſe endowed with ſenſe, I ſhall conſider;

I. Some things common to them all.

II. Things peculiar to their tribes.

I. The things in common, which I intend to take notice of, are theſe ten:

1. The five *ſenſes*, and their organs.
2. The great inſtrument of vitality, *reſpiration.*
3. The *motion*, or loco-motive faculty of animals.
4. The *place*, in which they live and act.
5. The *balance* of their numbers.
6. Their *food.*
7. Their *cloathing.*
8. Their *houſes*, *neſts*, or *habitations.*
9. Their methods of *ſelf-preſervation.*
10. Their *generation* and *conſervation* of their ſpecies by that means.

CHAP. I.

Of the five Senses in general.

THE firſt thing to be conſidered, in common to all the ſenſitive creatures, is, their faculty of *ſeeing*, *hearing*, *ſmelling*, *taſting*, and *feeling*; and the *organs* miniſtring to theſe five *ſenſes*, together with the exact accommodation of thoſe ſenſes, and their organs, to the ſtate and make of every tribe of animals (*a*). The conſideration of which particulars alone, were there no other demonſtrations of God, is abundantly ſufficient to evince the infinite wiſdom, power, and goodneſs of the great Creator. For who can but ſtand amazed at the glories of theſe works! at the admirable artifice of them! and at their noble uſe and performances! For ſuppoſe an animal, as ſuch, had breath and life, and could move itſelf hither and

(*a*) *Ex ſenſibus ante cætera homini tactus, deinde guſtatus: reliquis ſuperatur à multis. Aquilæ clariùs cernunt: vultures ſagaciùs odorantur, liquidiùs audiunt talpæ obrutæ terrâ, tam denſo atque ſurdo naturæ elemento.*—"The moſt exquiſite of the ſenſes in man are the touch and taſte; in the other ſenſes he is ſurpaſſed by many animals. The eagles have a clearer ſight; the vultures are more ſagacious in the ſenſe of ſmelling: the moles buried in the earth, the denſeſt and moſt impenetrable of elements, ſurpaſs us in acuteneſs of hearing."—*Plin. Nat. Hiſt.* l. 10. c. 69.

 thither;

thither; yet how could it know whither to go, what it was about, where to find its food, how to avoid thousands of dangers (*b*), without sight! How could man, particularly, view the glories of the heavens, survey the beauties of the fields, and enjoy the pleasure of beholding the noble variety of amusing objects, that do, above us in the heavens, and here in this lower world, present themselves to our view every where; how enjoy this, I say, without that admirable sense of *sight* (*c*)! How could also the animal, without *smell* and *taste*, distinguish its food, and discern between wholesome and unwholesome; besides the pleasures of delightful odours, and relishing gusto's! How, without that other sense of *hearing*, could it discern many dangers that are at a distance, understand the mind of others, perceive the harmonious sounds of music, and be delighted with the melodies of the winged choir, and all the rest of the harmonies the Creator hath provided for the delight and pleasure of his creatures! And lastly,

(*b*) *Subjacent oculi, pars corporis pretiosissima, & qui lucis usu vitam distinguunt à morte.*—"Under the forehead lie the eyes, the most precious of our organs, and which by their perception of the light, indicate the distinction between life and death." *Plin. Nat. Hist.* l. 11. c. 37.

(*c*) *Fœminæ aliquæ Megarenses solis oculis discernere valebant inter ova quæ ex gallinâ nigrâ, & quæ ex albâ nata sunt,*—"That some of the Megarean women could distinguish, solely by the eye, between the eggs of a black hen and those of a white,"—is what is affirmed (how truly I know not) by *Grimald. de Lumin. & Color. Pr.* 43. *sect.* 60.

how

how could man, or any other creature, diſtinguiſh pleaſure from pain, health from ſickneſs, and conſequently be able to keep their body ſound and entire, without the ſenſe of *feeling*! Here, therefore, we have a glorious œconomy in every animal, that commandeth admiration, and deſerveth our contemplation: as will better appear by coming to particulars, and diſtinctly conſidering the proviſion which the Creator hath made for each of theſe ſenſes.

CHAP. II.

Of the Eye.

FOR our clearer proceeding in the confideration of this noble part (*a*), and underftanding its œconomy, I fhall confider,

(*a*) *In diffectionibus anatomicis vix aliquid admirabilius, aut artificiofius ftructurâ oculi humani, meo quidem judicio, occurrit: ut meritò, per excellentiam, Creatoris appelletur miraculum.*—" In anatomical diffections, there is fcarcely any thing which, in my opinion, is more admirable or more confummately artificial than the ftructure of the eye, fo that it is defervedly termed by way of excellence the Miracle of the Creator's power."—*Gul. Fabr. Hildan. Cent.* 2. *Obferv.* 1.

So likewife, that accurate furveyor of the eye, Dr. *Briggs*, whofe *Ophthalmography* I have met with fince my penning this part of my furvey. His character of this curious piece of God's work is, *Inter præcipuas corporis animati partes, quæ magni Conditoris noftri fapientiam oftendunt, nulla fanè reperitur, quæ majori pompâ elucet quàm ipfe oculus, aut quæ elegantiori formâ concinnatur. Deum enim aliæ partes vel minori fatellitio ftipantur, vel in tantam venuftatem haud affurgunt: ocelli peculiarem honorem & decus à fupremo Numine efflatum referunt, & nunquam non ftupendæ fuæ potentiæ characteres repræfentant. Nulla fanè pars tam divino artificio & ordine, &c.*—" Among thofe parts of the animated body, which chiefly prove the wifdom of our great Creator, there is none more eminent or illuftrious than the eye; none more elegantly or curioufly framed. Other parts which fcarcely arife to fuch beauty, may be faid to form the inferior train of the divine pomp and majefty: but the eyes, in a peculiar manner, fpeak forth the dignity and honour of the Supreme Being, and reprefent in lively characters his ftupendous power. No part is framed with fuch divine fkill and fymmetry."—*Cap.* 1. *fect.* 1.

1. The

1. The *form* of the eye.
2. Its *ſituation* in the body.
3. Its *motions*.
4. Its *ſize*.
5. Its *number*.
6. Its *parts*.
7. The *guard* and *ſecurity* Nature hath provided for this ſo uſeful a part.

As this eminent part hath not been pretermitted by authors, that have made it their particular deſign and buſineſs to ſpeak of the works of GOD; ſo divers of the aforeſaid particulars have been touched upon by them. And therefore I ſhall take in as little as poſſible of what they have ſaid, and as near as I can, mention chiefly what they have omitted. And,

1. For the *form* of the eye; which is for the moſt part globous, or ſomewhat of the ſphæroidal form, which is far the moſt commodious optical form, as being fitteſt to contain the humours within, and to receive the images of objects from without (*b*). Was it a cube, or of any multangular form,

(*b*) It is a good reaſon *Friar Bacon* aſſigns for the ſphæricity of the eye: *Nam ſi eſſet planæ figuræ, ſpecies rei majoris oculo non poſſet cadere perpendiculariter ſuper eum—cùm ergò oculus videt magna corpora, ut ferè quartam cæli uno aſpectu, manifeſtum eſt, quòd non poteſt eſſe planæ figuræ, nec alicujus niſi ſphæricæ, quoniam ſuper ſphæram parvam poſſunt cadere perpendiculares infinitæ, quæ à magno corpore veniunt, & tendunt in centrum ſphæræ: et ſic magnum corpus poteſt ab oculo parvo videri.*—" For if it were of a plain ſurface, the figure of any object greater than the eye

form, ſome of its parts would lie too far off (*c*), and ſome too nigh thoſe lenticular humours, which by their refractions cauſe viſion. But by means of the form before-mentioned, the humours of the eye are commodiouſly laid together, to perform

eye itſelf could not fall perpendicularly upon it. Since, then, the eye can behold great objects, as for inſtance, almoſt a fourth part of the heavens at one view, it is manifeſt that for this purpoſe it could not have been of a plain figure, or of any other than a ſpherical: for an infinite number of perpendicular lines may fall upon a ſmall ſphere coming from all the great objects around, and tending to the center of the ſphere. And thus a very great body can be ſeen by the ſmalleſt eye." For the demonſtration of which he hath given us a figure.—*Rog. Bacon. Perſpect. Diſtinct.* 4. c. 4.

Dr. *Briggs* ſaith, *Pars antica, (ſive cornea,) convexior eſt poſticâ: hâc enim ratione radii meliùs in pupillam detorquentur, & oculi fundus ex alterâ parte in majorem (propter imagines rerum ibidem delineandas) expanditur.*—" The fore-part or *cornea* is more convex than the hinder-part: by this means the rays are the better converged upon the pupil: and on the other hand the back-part of the eye is the more expanded, that it may contain a greater number of images."—*Ibid. ſect.* 2.

(*c*) Suppoſe the eye had the *retina*, or back part, flat for the reception of the images, as in plate D fig. 5. ABA: it is manifeſt, that if the extremes of the image AA were at a due focal diſtance, the middle B would be too nigh the cryſtalline, and conſequently appear confuſed and dim; but all parts of the *retina* lying at a due focal diſtance from the cryſtalline, as at ACA, therefore the image painted thereon is ſeen diſtinct and clear. Thus in a dark room, with a lens at a hole in the window, (which *Sturmius* calls his artificial eye, in his *Exercit. Acad.* one of which he had made for his pupils, to run any where on wheels): In this room, I ſay, if the paper that receives the images be too nigh, or too far off the lens, the image will be confuſed and dim; but in the focus of the glaſs, diſtinct, clear, and a pleaſant ſight.

their office of refraction; and the *retina*, and every other part of that little darkened cell, is neatly adapted regularly to receive the images from without, and to convey them accordingly to the common senfory in the brain.

To this we may add the aptitude of this figure to the motion of the eye, for it is neceffary for the eye to move this way, and that way, in order to adjuft itfelf to the objects it would view: fo by this figure it is well prepared for fuch motions, fo that it can with great facility and dexterity direct itfelf as occafion requires.

And as the figure, fo no lefs commodious is,

2. The *fituation* of the eye, namely, in the head (*d*), the moft erect, eminent part of the body, near the moft fenfible, vital part, the brain. By its eminence in the body, it is prepared to take in the more (*e*) objects. And by its fituation in the head, befides its proximity to the brain, it is in the moft convenient place for defence and fecurity. In the hands, it might indeed (in man) be

(*d*) *Blemmyis traduntur capita abeffe, ore & oculis pectori affixis.*—"It is faid, that the Blemmyans have no heads; and that their mouths and eyes are placed in their breafts."—*Plin. Nat. Hift.* l. 5. c.8.—*Occidentem versùs quofdam fine cervice oculos in humeris habentes.*—"To the Weft there are certain races of people who have no necks, and have their eyes in their fhoulders."—*Ibid.* l. 7. c. 2. From thefe, and other fuch like fables, in this laft cited chapter of *Pliny*, no doubt our famous romancer Sir *J. Mandevile* had his romantic ftories related in his travels.

(*e*) See *book* v. *chap.* ii. *note* (*e*).

rendered

rendered more eminent than the head, and be turned about here and there at pleaſure: but then it would be expoſed to many injuries in that active part, and the hands (*f*) rendered a leſs active and uſeful part. And the like may be ſaid to its ſite, in any other part of the body but where it is. But in the head, both of man and other animals, it is placed in a part that ſeems to be contrived and made chiefly for the action of the principal ſenſes.

Another thing obſervable in the ſite of the eye, is the manner of its ſituation in the head, in the fore-part, or ſide-part thereof, according to the particular occaſions of particular animals. In man, and ſome other creatures, it is placed to look directly forward chiefly; but withal it is ſo ordered, as to take in near the hemiſphere before it. In birds, and ſome other creatures, the eyes are ſo ſeated, as to take in near a whole ſphere, that they may the better ſeek their food, and eſcape dangers. And in ſome creatures they are ſeated, ſo as to ſee beſt behind them (*g*), or on each ſide, whereby

(*f*) *Galen* deſerves to be here conſulted, who in his book *De Uſu Partium*, from many conſiderations of the hand, ſuch as what is here mentioned, as alſo its ſtructure, ſite, and uſe, largely proves and reflects upon the wiſdom and providence of the Contriver and Maker of that part.

(*g*) Thus in *hares* and *conies*, their eyes are very protuberant, and placed ſo much towards the ſides of their head, that their two eyes take in nearly a whole ſphere: whereas in *dogs*, (that purſue them,) the eyes are ſet more forward in the head, to look that way more than backward.

they

they are enabled to fee their enemy that purfues them that way, and fo make their efcape.

And for the affiftance of the eyes, and fome of the other fenfes in their actions; the head is generally made to turn here and there, and move as occafion requires. Which leads me to the,

3. Thing to be remarked upon, the *motions* of the eye itfelf. And this is generally upwards, downwards, backwards, forwards, and every way (*h*), for the better, more eafy, and diftinct reception of the vifual rays.

But where Nature any way deviateth from this method, either by denying motion to the eyes, or the head (*i*), it is a very wonderful provifion fhe hath

(*h*) *Sed lubricos oculos fecit* [Natura] *& mobiles, ut & declinarent fiquid noçeret; & afpectum, quo vellent, facilè converterent.* "Nature has made the eyes flippery and eafily moved, that they may quickly turn afide from any thing that could hurt them, and turn with facility to any object of fight."—*Cicer. de Nat. Deor.* l. 2. c. 57.

(*i*) *The eyes of* fpiders, (in fome four, in fome fix, and in fome eight,) *are placed all in the fore-front of their head, (which is round, and without any neck,) all diaphanous and tranfparent, like a locket of diamonds,* &c. *Neither wonder why Providence fhould be fo anomalous in this animal, more than in any other we know of. For,* 1. *Since they wanting a neck, cannot move their head, it is requifite that defect fhould be fupplied by the multiplicity of eyes.* 2. *Since they were to live by catching fo nimble a prey as a fly is, they ought to fee her every way, and to take her* per faltum, *(as they do,) without any motion of the head to difcover her: which motion would have fcared away fo timorous an infect.* Power's Microf. Obferv. *p.* 11.

The

hath made in the cafe. Thus for a remedy of this inconvenience, in fome creatures their eyes are fet out at a diftance (*k*) from the head, to be circumvolved here and there; or, one this, the other that way, at pleafure. And in creatures, whofe eyes are without motion, as in divers infects; in this cafe, either they have more than two eyes, or their eyes are nearly two protuberant hemifpheres, and each hemifphere often confifting of a prodigious number of other little fegments of a fphere (*l*). By which means thofe creatures are fo

The eyes of the cameleon *refemble a lens, or convex-glafs, fet in a verfatile globular focket, which fhe turneth backward, or any way, without moving her head; and ordinarily the one a contrary, or quite different way from the other.* Dr. *Goddard* in Phil. Tranf. No. 137.

But what is more extraordinary in this motion [of the *cameleon's* eye] *is to fee one of the eyes move, whilft the other remains immoveable; and the one to turn forward, at the fame time that the other looketh behind; the one to look up to the fky, when the other is fixed on the ground. And thefe motions to be fo extreme, that they do carry the* pupilla *under the creft which makes the eye-brow, and fo far into the* canthi, *or corners of the eyes, that the fight can difcern whatever is done juft behind it, and directly before, without turning the head, which is faftened to the fhoulders.* Mem. for a Nat. Hift. in Anatom. Diffect. at Parif. Diff. of Camel. *pag.* 22.

(*k*) *Snails* fend out their eyes at a diftance, they being contained in their four horns, *like atramentous fpots, fitted to the end of their horns, or rather to the ends of thofe black filaments or optic nerves, which are fheathed in their horns, as* Dr. *Power* wordeth it. Obf. 31. p. 36. So the ingenious Dr. *Lifter, Exercit. Anat. Cochl. & Limæ.*

(*l*) Vide *l.* 8. *c.* 3. *note* (*a*).

far

far from being denied any benefit of that noble and moſt neceſſary ſenſe of ſight, that they have probably more of it than other creatures, anſwerable to the rapidity of their flight, and briſk motion; and to their inqueſts after food, habitation, or repoſitories of generation, or ſuch other neceſſity of the animal.

4. Another admirable proviſion in the eye, is, its ſize; in ſome animals large, in ſome little. It would be endleſs here to enumerate particulars; as thoſe of quadrupeds, birds, inſects, and other terreſtrial animals. And as for fiſhes, they will fall under another part of my ſurvey.

I ſhall therefore only take notice of its ſize in one creature, the mole (*m*). As the habitation of that

(*m*) *Severinus* is of *Ariſtotle*'s, *Pliny*'s, and *Alb. Magnus*'s opinion, that the *mole* hath no ſight; *G. Seger* denies any humour to be therein, but thinks they may probably ſee, becauſe Nature made nothing in vain. But *Borrichius* ſaith, their eyes have *appendiculam nerveam in cerebrum euntem, cujus beneficio globuli illi* [the little eyes] *extra pellem facilè poterant exſeri, retrahique pro arbitrio.—In illis oculorum globulis humor aqueus copiosè ſatis natabat; cæterorum non niſi tenue veſtigium.*—" An appendage of nerves going into the brain, by means of which thoſe little eye-balls can at pleaſure be thruſt out beyond the ſkin, or drawn within it.—In thoſe little globules of the eyes, there was a copious aqueous humour, but very little appearance of the other humours."—*Blaſ. Anat. Anim.* c. 35.

Et quoniam Natura hoc vitæ genus ipſi deſtinavit, etiam perquàm exiguos oculos—dedit eo concilio, ut ii, pretioſiſſima corporis pars, à terræ pulvere nè affligerentur. Ii inſuper pilis tecti, &c. Humores illis oculis inſunt, & tunica nigra, uvea, ſī prodit. Ad hos tramite alio nervus venit.—" And ſince Nature has deſtined the animal to that kind of life, ſhe has given it very ſmall eyes, that

 this

that uncouth animal is wholly ſubterraneous, its lodging, its food, its exerciſes, nay, even all its paſtimes and pleaſures are in thoſe ſubterraneous receſſes and paſſages, which its own induſtry hath made for itſelf; ſo it is an admirable proviſion made in the ſize of the eye of that little creature, to anſwer all its occaſions, and at the ſame time to prevent inconveniences. For as a little light will ſuffice an animal living always under ground; ſo the ſmalleſt eye will abundantly ſupply that occaſion. And as a large protuberant eye, like that of other animals, would much annoy this creature in its principal buſineſs, of digging for its food

this moſt precious part of its body might not be endangered by the duſt or earth. They are, moreover, covered with hair, &c. There are humours in thoſe eyes, and the duſky tunicle or *uvea* preſents itſelf. To theſe a nerve reaches by another courſe."—*Schneider in Blaſ.* Ibid.

Some time ſince I made divers accurate diſſections of the *eyes* of *moles*, with the help of microſcopes, having a doubt whether what we take to be eyes, were ſuch or no. And upon a ſtrict ſcrutiny I plainly could diſtinguiſh the *vitreous* and *cryſtalline* humours, yea, the *ligamentum ciliare*, and the atramentaceous *mucus*. The *pupil* I could manifeſtly diſcern to be round, and the *cornea* copped, or conical. The eye is at a great diſtance from the brain, the optic nerve very ſlender and long, reaching from the eye through the intermediate fleſh, and ſo paſſeth to the brain, along with the pair of nerves reaching to the noſe, which are much the largeſt that are in all the animal. Theſe creatures, I imagine, have the faculty of withdrawing their eyes, if not quite into the head, (as *ſnails*,) yet more or leſs within the hair, as they have more or leſs occaſion to uſe or guard their eyes.

Galen ſaith, *moles* have eyes, the *cryſtalline* and *vitreous* humours, encompaſſed with *tunics*. *De Uſ. Part.* l. 14. c. 6. So accurate an anatomiſt was he for his time.

and

and paſſage; ſo it is endowed with a very ſmall one, commodiouſly ſeated in the head, and well fenced and guarded againſt the annoyances of the earth.

5. Another thing remarkable in this noble part of animals, is, its *numbers*; no leſs than two (*n*) in any inſtance, that I know of; and in ſome animals more, as I have already hinted (*o*).

Now this is an admirable proviſion; firſt, for the convenience of taking in the larger angle, or ſpace: and in the next place, the animal is by this proviſion, in ſome meaſure, prepared for the misfortune of the loſs of one of theſe noble, and neceſſary organs of its body.

But then beſides all this, there is another thing conſiderable in this multiplicate number of the eye; and that is, that the object ſeen is not multiplied as well as the organ, and appears but one, though ſeen with two or more eyes (*p*). A manifeſt

(*n*) *Pliny* tells us of a ſort of *heron* with but one eye, but it was only by hear-ſay. *Inter aves ardeolarum genere, quos Leucos vocant, altero oculo carere tradunt.*—" Among the birds of the heron ſpecies, there are ſome called *Leucoi*, which are ſaid to have but one eye."—*Nat. Hiſt.* l. 11. c. 37. So the king of the *Nigræ*, that hath but one eye, and that in his forehead, *l.* 6. *c.* 30. Which fables I take notice of more for the reader's diverſion, than any truth in them.

(*o*) *Supra*, note (*i*).

(*p*) The moſt celebrated anatomiſts differ greatly about the reaſon, why we ſee not double with two eyes. This *Galen*, and others after him, generally thought to be from a coalition or decuſſation of the optic nerves, behind the *os ſphenoïdes*. But whether they decuſſate, coaleſce, or only touch one another, they do not well agree. The *Bartholines* expreſsly aſſert, they are united, *Non per ſimplicem contactum vel. interſectionem in ho-*

 mine,

feſt ſign of the infinite ſkill of the Contriver of this ſo noble a part, and of the exquiſite art He employed

mine, ſed totalem ſubſtantiæ confuſionem.—"Not by ſimple contact or interſection in man, but by a total confuſion of ſubſtance."—Anat. l. 3. c. 2. And whereas *Veſalius*, and ſome others, had found ſome inſtances of their being diſunited; they ſay, *Sed in pleriſque ordinariè confunditur interior ſubſtantia, ut accuratâ diſquiſitione deprehendi.*—"But in moſt inſtances the interior ſubſtance is blended together, as I have diſcovered on an accurate examination."

But our learned Dr. *Gibſon* (*Anat.* l. 3. c. 10.) ſaith, they *are united by the cloſeſt conjunction, but not confuſion of their fibres.*

But others think the reaſon is not from any coaleſcence, contact, or croſſing of the optic nerves, but from a ſympathy between them. Thus Monſieur *Cartes* is of opinion, that the *fibrillæ*, conſtituting the medullary part of thoſe nerves, being ſpread in the *retina* of each eye, have each of them correſponding parts in the brain; ſo that when any of thoſe *fibrillæ* are ſtruck by any part of an image, the correſponding parts of the brain are thereby affected, and the ſoul thereby informed, &c. But ſee more hereafter under note (*oo*), from *Cartes* himſelf.

Somewhat like this is the notion of our judicious Dr. *Briggs*, who thinks the optic nerves of each eye conſiſt of *homologous fibres*, having their riſe in the *thalamus nervorum opticorum*, and thence continued to both the *retinæ*, which are made of them: and farther, that thoſe *fibrillæ* have the ſame paralleliſm, tenſion, &c. in both eyes; and conſequently when an image is painted on the ſame correſponding, ſympathizing parts of each *retina*, the ſame effects are produced, the ſame notice or information is carried to the *thalamus*, and ſo imparted to the ſoul, or judging faculty. That there is ſuch an Ὁμοιοπάθεια, or ſympathy, between the *retinæ*, &c. he makes very probable, from the enſuing of double viſion upon the interruption of the paralleliſm of the eyes; as when one eye is depreſſed with the finger, or their ſymphony interrupted by diſeaſe, drunkenneſs, &c. And laſtly, that ſimple viſion is not made in the former way, *viz.* by a decuſſation or conjunction

employed in the formation thereof. But the design and ſkill of the infinite Workman will beſt be ſet forth by,

6. Surveying the *parts* and *mechaniſm* of this admirable organ the eye. And here indeed we cannot but ſtand amazed, when we view its admirable fabric, and conſider the prodigious exactneſs, and the exquiſite ſkill employed in every part miniſtering to this noble and neceſſary ſenſe. To paſs by its arteries and veins, and ſuch other parts common to the reſt of the body, let us caſt our

tion of the optic nerves, he proves, becauſe thoſe nerves are but in few ſubjects decuſſated, and in none conjoined otherwiſe than by a bare contact, which is particularly manifeſt in fiſhes; and in ſome inſtances it hath been found, that they have been ſeparated without any double viſion enſuing thereupon. Vide *Brig. Opthalmogr.* c. 11. and 5. and *Nov. Viſ. Theor. paſſim.*

What the opinion of our juſtly eminent Sir *Iſaac Newton* is, may be ſeen in his *Optics*, Qu. 15. *Are not the ſpecies of objects ſeen with both eyes, united where the optic nerves meet before they come into the brain, the fibres on the right ſide of both nerves uniting there,* &c.? *For the optic nerves of ſuch animals as look the ſame way with both eyes, (as of men, dogs, ſheep, oxen,* &c.) *meet before they come into the brain; but the optic nerves of ſuch animals as do not look the ſame way with both eyes, (as of fiſhes, and of the cameleon,) do not meet, if I am rightly informed.* Newt. Opt. Q. 15. *

* The ſame ſubject has been examined with much acuteneſs by Dr. Porterfield in his *Treatiſe on the Eye*; by Dr. Reid in his *Enquiry into the Human Mind*; and by Dr. Wells in his *Eſſay on ſingle Viſion*; each of whom has ſuggeſted a different hypotheſis to account for this extraordinary phenomenon. An abſtract of the theories of all thoſe writers may be found in *Encyclopedia Britannica*, under the article *Optics*, vol. xiii. p. 299. EDITOR.

eye on its *muſcles*. Theſe we ſhall find exactly and neatly placed for every motion of the eye. Let us view its *tunics*, and theſe we ſhall find ſo admirably ſeated, ſo well adapted, and of ſo firm a texture, as to fit every place, to anſwer every occaſion, and to be proof againſt all common inconveniences and annoyances. Let us examine its three *humours*, and theſe we ſhall find all of exquiſite clearneſs and tranſparency, for an eaſy admiſſion of the rays; well placed for the refracting of them, and formed (particularly the *cryſtalline humour*) by the niceſt laws of optics, to collect the wandering rays into a point. And to name no more, let us look into its darkened cell, where thoſe curious humours lie, and into which the glories of the heavens and the earth are brought, and exquiſitely pictured; and this cell we ſhall find, without, well prepared by means of its texture, aperture, and colour, to fence off all the uſeleſs or noxious rays; and within, as well coated with a dark tegument, that it may not reflect, diſſipate, or any way confuſe or diſturb the beneficial rays (*q*).

But

(*q*) *Nigra eſt* [uvea] *ut radios (ab oculi fundo ad anteriorem ejus partem reflexos) obumbret; nè hi (ut ait clar. Carteſius) ad oculi fundum retorti ibidem confuſam viſionem efficerent. Alia forſan ratio hujus nigredinis ſtatuatur, quòd radii in viſione ſuperflui, qui ab objectis lateralibus proveniunt hoc ritu abſorbeantur. Ita enim è loco obſcuro interdiu objecta optimè intuemur, quia radii tunc temporis circumfuſo lumine non diluuntur.*—" The *uvea* is black, in order that it may obſcure the rays which are reflected from the bottom of the eye to its fore-part; leſt, as Deſcartes obſerves,

But to defcend to particulars, although it would be a great demonftration of the glory of God, yet would take up too much time, and hath been in fome meafure done by others that have written of God's works. Paffing over, therefore, what they have obferved, I fhall, under each principal part, take a tranfient notice of fome things they have omitted, or but flightly fpoken of.

And my firft remark fhall be concerning the *mufcles* of the eye, and their equilibration. Nothing can be more manifeftly an act of contrivance and defign, than the *mufcles* of the eye, admirably adapted to move it any, and every way; upwards, downwards, to this fide or that, or howfoever we pleafe, or there is occafion for, fo as to always keep that parallelifm of the eye which is neceffary to true vifion. For the performance of which fervice, the form, the pofition, and the due ftrength of each mufcle is admirable. And here I might inftance the peculiar and artificial ftructure of the *trochlearis*, (Plate D, fig. 2.) and the augmentation of its power by the *trochlea* (*r*); the

ferves, thefe fhould be thrown back again upon the bottom, and thus occafion confufed vifion. Perhaps another primary caufe may be affigned for this blacknefs of the *uvea*, viz. that the fuperfluous rays which proceed from lateral objects may be abforbed. Thus we obferve, that thofe illuminated objects which are feen from a dark ftation are moft diftinctly beheld, becaufe the rays proceeding from them are not obliterated by the circumambient light."—*Briggs's Ophthal.* c. 3. fect. 5.

(*r*) *Admirandum Dei artificium ex diverforum animalium comparatione indies evadit manifeftius. Mirantur omnes trochlearem*

 in

the magnitude and ſtrength of the *attollent muſcle*, ſomewhat exceeding that of its antagoniſt; the peculiar muſcle, called the *ſeventh*, or *ſuſpenſory muſcle* (*s*), given to brutes, by reaſon of the prone

in oculis hominum & quadrupedum, & quidem jure: ſed admirationem omnem ſuperat, quòd ſine trochleâ oculum movens in avibus novum genus trochleæ longè artificioſiùs nictitandi membranæ dederit.—"We daily diſcover new proofs of the wonderful art of the Supreme Being, from comparing the ſtructure of different animals. All juſtly admire the *trochlear* muſcle in the eyes of men and quadrupeds: but what is far more wonderful, is the nictitating membrane which in birds ſupplies the place of the *trochlea*."—*Blaſ. Anat. Animal.* p. 2. c. 4. *ex Stenon.*

[Muſculum trochlearem] *per intermedium trochleam traductum, nunquam intueor, quin admirabundus mecum,* Ὁ Θεὸς, *exclamem,* οὐ μόνον ἀεὶ γεωμετρεῖ, ἀλλὰ καὶ ἀεὶ μηχανᾶται.—"I never behold the *trochlear* muſcle paſſing through the *trochlea*, without exclaiming to myſelf in admiration, "Not only has God contrived all with the moſt accurate proportions, but with the moſt wonderful mechaniſm."—*I. C. Sturmii Exercit. Acad.* 9. *de Viſ. Org. & Rat.* c. 3: ſect. 4. p. 446.

(*s*) *Obſervare eſt quod quadrupedes, qui oculos in terram pronos, ac pendulos gerunt, muſculum peculiarem habent, quo oculi globus ſuſpenditur.—Hoc muſculo bos, equus, ovis, lepus, porcus, &c. præditi ſunt: hoc etiam canis inſtruitur, ſed alio modo conformatum habet.*—"It is obſervable, that quadrupeds who have their eyes hanging downwards, and inclining to the earth, have a peculiar muſcle, by which the ball of the eye is ſuſpended.—The cow, the horſe, the ſheep, the ſwine are poſſeſſed of this muſcle: the dog has it likewiſe, though it is formed in that animal in a different manner."—*Willis de An. Brut.* p. 1. c. 15.

Of this opinion alſo was *Bartholine, Anat.* l. 3. c. 8. and divers other eminent anatomiſts.

But Dr. *Briggs* is of opinion that the *adnata*, and the other muſcles ſufficiently anſwer all thoſe ends aſcribed to that muſcle by

prone poſture of their bodies, and frequent occaſions to hang down their heads: and I might ſpeak alſo of the peculiar origin and inſertion of the *lower oblique muſcle* (*t*), which is very notable,

by former anatomiſts, and thinks, *probabiliùs itaque eſſe hunc muſculum nervi optici actionem (per vices) confirmare, nè à prono brutorum inceſſu & copioſo affluxu humorum debilitetur.*—"That this muſcle ſtrengthens the action of the optic nerve, leſt in the brute animals it ſhould be weakened by their prone poſition, and by the great confluence of the humours."—*Ophthal.* c. 2. ſect. 2.

The *muſculus ſuſpenſorius* being in the *porpeſs*, as well as brutes, Dr. *Tyſon* thinks the uſe of it is not to ſuſpend the bulk of the eye; but rather by its equal contraction of the *ſclerotis*, to render the ball of the eye more or leſs ſpherical, and ſo fitter for viſion. *Tyſon's Anat. of the Porpeſs*, p. 39.

(*t*) *Muſculus obliquus inferior oritur à peculiari quodam foramine in latere orbitæ ocularis facto, (contra quàm in cæteris, &c.) quo fit ut ex unâ parte à muſculo trochleari, ex alterâ verò ab hujus muſculi commodiſſimâ poſitione, oculus in æquilibrio quodam conſtitutus, irretorto obtutu verſus objecta feratur, nec plus juſto accedat verſus internum externumve canthum; quæ quidem libratio omnino nulla fuiſſet, abſque hujus muſculi peculiari originatione (cujus ratio omnes hucuſque anatomicos latuit).*—"The oblique inferior muſcle has its origin from a certain opening in the ſide of the orbit of the eye, (not as the other muſcles,) ſo that the eye kept in a ſort of equipoiſe by the *trochlear* muſcle on one ſide, and by this on the other, can point itſelf to objects with a ſteady direction, and is not carried too much either towards the inward or outward corner. (Plate D, fig. 2.) Without this peculiar origin of the muſcle, there would be no ſuch balance: which reaſon hath hitherto eſcaped all our anatomiſts." And ſo this curious anatomiſt goes on to ſhew farther the ſtupendous artifice of the great Creator in this poſition of the *oblique muſcles*. *Briggs's Nova Viſ. Theor.* p. 11. *meo libro.*

and

and many other things relating to theſe parts; but it would be tedious to deſcend too much to thoſe admirable particulars. And therefore to cloſe up theſe remarks, all I ſhall farther take notice of, ſhall be only the exquiſite equilibration of all theſe *oppoſite* and *antagoniſt muſcles*, affected partly by the equality of the ſtrength; which is the caſe of the *adducent* and *abducent muſcles*; partly by their peculiar origin, or the addition of the *trochlea*, which is the caſe of the *oblique muſcles* (*u*); and partly by the natural poſture of the body, and the eye, which is the caſe of the *attollent* and *depriment muſcles*. By this ſo curious and exact a libration, not only unſeemly contortions and incommodious vagations of the eye are prevented, but alſo it is able with great readineſs and exactneſs to apply itſelf to every object.

As to the *tunics* of the eye, many things might be taken notice of, the prodigious fineneſs of the *arachnoïdes*, the acute ſenſe of the *retina*, the

(*u*) Beſides thoſe particular motions which the eye receives from the *oblique muſcles*, and I may add its libration alſo in ſome meaſure, ſome anatomiſts aſcribe another no leſs conſiderable uſe to them; namely, to lengthen and ſhorten the eye (by ſqueezing and compreſſing it) to make it correſpond to the diſtances of all objects, according as they are nigh or far off. Thus the ingenious Dr. *Keil; the aqueous humour being the thinneſt and moſt liquid, eaſily changeth its figure, when either the* ligamentum ciliare *contracts, or both the* oblique muſcles *ſqueeze the middle of the ball of the eye, to render it oblong when objects are too near us.* Keil's Anat. *chap.* 4. *ſect.* 4. See *note* (*y*).

delicate

delicate tranſparency of the *cornea* (*w*), and the firm and ſtrong texture of that and the *ſclerotica* too; and each of them, in theſe and every other reſpect, in the moſt accurate manner adapted to the place in which it is, and the buſineſs it is there to perform. But for a ſample, I ſhall only take notice of that part of the *uvea* which makes the *pupil*. It hath been obſerved by others, particularly by our honourable Founder (*x*), that as we are forced to uſe various apertures to our optic glaſſes, ſo Nature hath made a far more complete proviſion in the eyes of animals, to ſhut out too much, and to admit ſufficient light, by the dilatation and contraction of the pupil (*y*). But it deſerveth

(*w*) *Quis verò opifex præter Naturam, quâ nihil poteſt eſſe callidiùs, tantam ſolertiam perſequi potuiſſet in ſenſibus? quæ primùm oculos membranis tenuiſſimis veſtivit, & ſepiit; quas primam perlucidas fecit, ut per eas cerni poſſet: firmas autem, ut continerentur.* —"What workman beſides Nature, than whom there can be none more ſkilful, could ſhew ſuch admirable artifice in the organs of ſenſe? The eyes ſhe has covered and defended with the fineſt membranes, tranſparent to admit the rays, and firm at the ſame time, that they may be kept within the orbits."—*Cic. de Nat. Deor.* l. 2. c. 57.

(*x*) *Boyle* of *Final Cauſes*.

(*y*) It is eaſy to be obſerved, that the *pupil* openeth in dark places; as alſo when we look at far diſtant objects, but contracts by an increaſe of light, and when the objects are nigh. This motion of the *pupil*, ſome ſay, is effected by the circular and ſtrait fibres of the *uvea*, and ſome attribute it to the *ligamentum ciliare*. Yet I have no great doubt but that they both concur in that action, and that the *ligamentum ciliare* doth, at the ſame time the pupil opens or ſhuts, dilate or compreſs

deſerveth our eſpecial remark, that theſe pupils are in divers animals of divers forms, according to their peculiar occaſions. In ſome (particularly in man) it is round; that being the moſt proper figure for the poſition of our eyes, and the uſe we make of them both by day and night. In ſome other animals it is of a longiſh form; in ſome tranſverſe (z), with its aperture large. which is an

preſs the *cryſtalline*, and bring it nigher unto, or carry it farther off the *retina*. For the ſtructure of the *ligamentum ciliare*, and its two ſorts of fibres, drawn with the help of a microſcope, I ſhall refer to Mr. *Cowper's Anat. T.* 11.

(z) *In bove, caprâ, equo, ove, & quibuſdam aliis elliptica eſt* (pupilla) *ut eo magis in hiſce forſan animalibus, quæ prono inceſſu victum in agris quæritant, radios laterales ad mala & incommoda utrinque devitanda admittat.*—" In the cow, the goat, the horſe, the ſheep, and ſome other animals, the pupil is of an elliptic form, for this reaſon perhaps, that in thoſe animals which walk with the head declining, the eye may admit the lateral rays, and thus avoid any object on either ſide that might offend them."—*Briggs's Opthal.* c. 7. ſect. 2.

Homini erecto, aliiſque, &c. caput erigere, & quaquaverſus circumſpicere ſolitis, plurima ſimul objecta, tum ſuprà, tum infrà, tum è latere utroque—viſu excipiuntur; quapropter oculi pupilla rotunda eſſe debet.—Attamen bovi, &c. caput ferè ſemper pronum—gerentibus, tantùm que coràm, & paulo à latere obſervantur, intuitu opus eſt: quapropter pupilla—oblonga eſt, &c.—" In man and other animals which are accuſtomed to erect the head, and to look every where around them, a great many objects are taken in by the eye, both from above, below, and from the ſides: for which purpoſes the pupil of the eye muſt have been round. But to the cow and other animals, which carry the head almoſt always in a prone poſition, it is neceſſary to ſee only the objects before them, and thoſe that are a little to a ſide. and therefore in them the pupil is oblong."—*Willis de Anim. Brut.* p. 1. c. 15.

admirable proviſion for ſuch creatures to ſee the better laterally, and thereby avoid inconveniences, as well as help them to gather their food on the ground, both by day and night. In other animals the fiſſure of the pupil is erect (*aa*), and alſo capable of opening wide, and ſhutting up cloſe. The latter of which ſerves to exclude the brighter light of the day, and the former to take in the more faint rays of the night, thereby enabling thoſe nocturnal animals (in whom generally this erect form of the pupil is) to catch their prey with the greater facility in the dark (*bb*), to ſee upwards and

(*aa*) Thus *cats* (their pupils being erect, and the ſhutting of their eye-lids tranſverſe thereunto) can ſo cloſe their pupil, as to admit of, as it were, one only ſingle ray of light; and by throwing all open, they can take in all the fainteſt rays. Which is an incomparable proviſion for theſe animals, that have occaſion to watch and way-lay their prey both by day and night.

(*bb*) There is beſides this large opening of the pupil, in ſome nocturnal animals, another admirable proviſion enabling them to catch their prey in the dark; and that is a radiation of the eyes: of which Dr. *Willis* thus; *Hujus uſus eſt oculi pupillam, quaſi jubare inſito, illuminare, ut res noctu, & in tenebris poſitas conſpicere valeat: quare in fele plurimum illuſtris eſt: at homini, avibus & piſcibus deeſt.*—"The uſe of this is to illuminate the pupil, as if by an internal beam of light, ſo as to render it capable of perceiving objects in the night, or in a dark place: Wherefore in the cat, it is very much illuminated: but there is no ſuch thing in man, in birds, or in fiſhes."—This illumination he ſpeaks of, is from the *tapetum*, in the bottom of the eye, or the ſhining of the *retina*, round the optic nerve.

Beſides

and downwards, to climb, *&c.* Thus much for the *tunics*.

The next thing I ſhall take notice of, will relate to the *humours* of the eye, and that only

Beſides which, he ſaith, the *iris* hath a faculty alſo, in ſome, of darting out rays of light, ſo as to enable them to ſee in the dark: of which he tells this ſtory; *Novi quendam cerebro calidiori præditum, qui poſt uberiorem vini generoſi potum in noƈte atratâ, ſive tenebris profundis, literas diſtinƈtè legere potuit. Cujus ratio videtur eſſe, quòd ſpiritus animales velut accenſi, adeòque ab hâc iride irradiantes, jubare inſito, medium illuminabant.*—"I knew a perſon of a warm temperament of brain, who after drinking heartily of wine, could diſtinƈtly read letters in the darkeſt night. The reaſon of which probably was, that the animal ſpirits being kindled, and ſparkling from the *iris* of the eye, illuminated the medium, as it were, by an internal beam of light."—*Willis, ibid.*

Such another thing, *Pliny* tells us, was reported of *Tiberius Cæſar; ferunt Tib. Cæſ. nec alii genitorum mortalium, fuiſſe naturam, ut expergefaƈtus noƈtu pauliſper, haud alio modo quam luce clarâ, contueretur omnia.*—"It is reported of Tiberius Cæſar, that he had the organs of ſight formed ſo differently from thoſe of other men, that when ſuddenly awakened in the night, he could perceive objeƈts as diſtinƈtly as if they were clearly illuminated."—*Nat. Hiſt.* l. 11. c. 37.

So Dr. *Briggs; Virum ſanè calidæ indolis novi in comitatu Bedfordienſi degentem, qui oculis felineis—donatus eſt: adeò ut epiſtolam—mirè admodum in loco obſcuro (ubi eadem mihi vix apparuit) perlegit. Hujus verò oculi (niſi quod pupillas inſigniores obtinuere) ab aliorum formatione neutiquam diſcrepabant.*—"I knew a man in Bedfordſhire of a warm temperament, who was poſſeſſed of cat's eyes, ſo that in a dark place he could read a letter diſtinƈtly, which to me was ſcarcely viſible. His eyes, however, had no apparent difference from thoſe of others, except that the pupils were more prominent."—*Ophthal.* c. 5. ſeƈt. 12.

concerning

concerning the mechanifm of the *cryftalline humour* (fee Plate D, fig. 1.); not its incomparable tranfparency; nor its exact lenticular form; nor its curious araneous membrane (*cc*), that con-

(*cc*) The *tunica aranea* is taken notice of by Friar *Bacon*, who calls it, *tela aranea*, and faith, *in hâc continetur—glaciale vel cryftallinum.*—" In this is contained the glaffy or cryftalline lens."—*Rog. Bacon's Perfpect. Diftinct.* 2. c. 3. The wrinkling of this, and the *cornea* (as the fkin is of old perfons) he thinks is the caufe of the obfcurity of the fight in fuch perfons. *Bacon, ib.* par. 2. c. 2. But this *tunic* fome deny, and others allow of. Dr. *A. M.* of *Trinity-College, Dublin*, (in his *Relat. of Anat. Obf.* in the eyes of animals, in a letter to Mr. *Boyle, ann.* 1682, annexed to his *Anat. Account of the Elephant burnt in* Dublin, p. 57.) affirms the *tunica aranea*, and faith, *I have often feen it before it was expofed to the air one minute, notwithftanding what Dr.* Briggs *faith to the contrary*, &c. But Dr. *Briggs* his opinion is, *Humor cryftallinus, nifi aeri diutiùs expofitus, vel lenitèr coctus (inftar lactis) cuticulam non acquirit: quæ verò impropriè, tunica aranea dicitur, cùm fit tantùm adventitia, ut in oculo bovis recens excecto appareat.*—" The cryftalline humour does not acquire a film unlefs it is long expofed to the air, or, like milk, is gently boiled. This film is improperly called *tunica aranea*, fince it is only an adventitious fubftance, as appears in a bull's eye recently cut out."—*Briggs's Ophthal.* c. 3.

The *cryftalline humour* being of a double fubftance, outwardly like a jelly, towards the centre as confiftent as hard fuet, upon occafion whereof its figure may be varied; which variation may be made by the *ligamentum ciliare*; Dr. *Grew* doth, upon thefe accounts, not doubt to afcribe to the *ligamentum ciliare*, a power of making the *cryftalline* more convex, as well as of moving it to or from the *retina*. See *Grew's Cofmolog. Sacr.* l. 1. c. 4. Now it is certain by the laws of optics, that fomewhat of this is abfolutely neceffary to diftinct vifion, inafmuch as the rays proceeding from near objects do more diverge,

conſtringeth and dilateth it, and ſo varieth its *focus*, (if any ſuch variation there be, as ſome af-

verge, and thoſe from diſtant objects leſs: which requires either that the *cryſtalline humour* ſhould be made more convex, or more flat; or elſe an elongation, or ſhortening of the eye, or of the diſtance between the *cryſtalline humour* and the *retina*.

But although Dr. *Briggs* (ſo good a judge) denies the *tunica cryſtallina*, contrary to the opinion of moſt former anatomiſts; yet there is great reaſon to conclude he was in a miſtake, in my opinion, from the obſervations of the *French anatomiſts*, of the *cryſtalline* of the eye of the *gemp* or *chamois*, who ſay, the *membrana arachnoïdes was very thick and hard, ſo that it was eaſily ſeparated from the cryſtallinus*. p. 145.

The ſame anatomiſts alſo favour the ſurmiſe of Dr. *Grew*. This [contraction of the fibres of the *ligamentum ciliare* on one ſide, and dilatation on the other] *would make us think that theſe fibres of the* ligamentum ciliare *are capable of contraction and voluntary dilatation, like that of the fibres of the muſcles; and that this action may augment or diminiſh the convexity of the* cryſtallinus, *according as the need which the diſtance of the objects may make it to have on the eye, to ſee more clearly and diſtinctly*. Anat. Deſcrip. of a *Bear*, p. 49.

Since my penning the foregoing notes, having, as critically as I could, diſſected many eyes of birds, beaſts, and fiſhes, I manifeſtly found the *membrana arachnoïdes*, and will undertake to ſhew it any one, with great eaſe and certainty. It is indeed ſo tranſparent, as not to be ſeen diſtinct from the *cryſtalline*. But if the *cornea* and *uvea* be taken off before, or the *vitreous humour* behind it, and the outſide of the *cryſtalline* be gently cut, the *arachnoïdes* may be ſeen to open, and the *cryſtalline* will eaſily leap out, and part from the *ligamentum ciliare*; which otherwiſe it would not do: for it is by the *arachnoïdes* braced to the *ligamentum ciliare*. This membrane or tunic, in the ox, is ſo ſubſtantial and ſtrong, though thin, that it yields to, or ſinks under the ſharpeſt lancet, and requires (for ſo thin and weak a membrane in appearance) a ſtrong preſſure to pierce it.

firm

firm with great probability,) nor laftly, its admirable approach to or from the *retina*, by the help of the *ciliar ligament* (*dd*), according as objects are far

(*dd*) As birds and fifhes are in divers things conformable, fo in fome fort they are in their eye; to enable it to correfpond to all the convergences and divergences of the rays, which the variations of each of the mediums may produce. For this fervice the *tunica choroeides* (in fifhes) hath a mufculous fubftance at the bottom of it, lying round the optic nerve, at a fmall diftance from it; by which means I imagine they are able to contract and dilate the *choroeides*, and thereby to lengthen and fhorten the eye: for the helping in which fervice, I imagine it is that the *choroeides* and *fclerotica* are in a great meafure parted, that the *choroeides* may have the greater liberty of acting upon the humours within.

But in birds I have myfelf found, that although the *choroeides* be parted from the *fclerotica*, yet the *choroeides* hath no mufcle, but inftead thereof a curious pectinated work, feated on the optic nerve, reprefented in plate D, fig. 4. In which *c. a. e. b. d.* reprefents the *choroeides* and *fclerotica; a. b.* the part of the *optic nerve* that is within the eye; *v. v. v.* the *vitreous humour; a. f. g. b.* the *pecten; h. i.* the *cryftalline.* For the reception of this *pecten*, the *optic nerve* comes farther within the eye than in other creatures. The ftructure of this *pecten* is very like that of the *ligamentum ciliare;* and in the eye of a *magpye*, and fome others, I could perceive it to be mufculous towards the bottom. This *pecten* is fo firmly fixed unto, or embodied in the *vitreous humour*, that the *vitreous humour* hangs firmly to it, and is not fo eafily parted from it. By which means all the motions of the *pecten* are eafily communicated to the *vitreous humour*, and indeed to all contained in the *choroeides*. And forafmuch as the *cryftalline* is connected to the *vitreous humour*, therefore alfo the alterations in the *vitreous humour* affect alfo the *cryftalline;* and the *cryftalline* is hereby brought nearer unto or farther from the *retina*, as occafion is.

far off or near, becaufe thefe things are what are ufually taken notice of; but that which I fhall obferve is the prodigious art and finery of its confti-

Befides all which obfervables in the *choroeides*, and inner eye, I have alfo found this farther remarkable in the *fclerotica*, and outer-part of the eye of birds, *viz.* that the fore-part of the *fclerotica* is horny and hard, the middle part thin and flexible, and *braces* intervene between the fore and hind part, running between the *choroeides* and *fclerotica;* by which means the *cornea*, and back-part of the eye, are brought to the fame conformity that the reft of the eye hath.

The great end and defign of this fingular and curious *apparatus* in the eyes, both of birds and fifhes, I take to be, 1. to enable thofe creatures to fee at all diftances, far off, or nigh; which (efpecially in the waters) requireth a different conformation of the eye. In birds alfo, this is of great ufe, to enable them to fee their food at their bill's end, or to reach the utmoft diftances their high flights enable them to view; as to fee over great tracts of fea or land, whither they have occafion to fly; or to fee their food or prey; even fmall fifhes in the waters, and birds, worms, *&c.* on the earth, when they fit upon trees, high rocks, or are hovering high in the air. 2. To enable thofe animals to adapt their eye to all the various refractions of their *medium*. Even the air itfelf varies the refractions, according as it is rarer or denfer, more or lefs compreffed; as is manifeft from the learned and ingenious Mr. *Lowthorp*'s experiment in *Phil. Tranf.* No. 257, and fome other experiments fince of the before-commended Mr. *Hawkfbee*, both in natural, rarified, and compreffed air; in each of which, the refractions conftantly varied in exact proportion to the rarity or denfity of the air. *Vid. Hawkfbee's Exp. p.* 175, *&c.*

Befides this conformity in general, between the eyes of birds and fifhes, *Du Hamel* tells us of a fingular conformity in the *cormorant*'s eye, and that is, that the *cryftalline* is globous, as in fifhes, to enable it to fee and purfue its prey under water: which *J. Faber*, in Mr. *Willughby*, faith they do *with wonderful fwiftnefs, and for a long time.* Will. Ornithol. p. 329.

tuent

tuent parts, it being, according to ſome late nice microſcopical obſervations (*ee*), compoſed of divers thin ſcales, and theſe made up of one ſingle minuteſt thread or fibre, wound round and round, ſo as not to croſs one another in any one place, and yet to meet, ſome in two, and ſome in more different centres; a web not to be woven, an *optic lens* not to be wrought by any art leſs than Infinite Wiſdom.

Laſtly, To conclude the parts of this admirable organ, I ſhall make only one remark more, and that is about its *nerves*. And here, among others, the admirable make of the *optic nerves* might de-

(*ee*) The *cryſtalline humour*, when dried, doth manifeſtly enough appear to be made up of many very thin ſpherical *laminæ*, or ſcales lying one upon another. Mr. *Lewenhoek* reckons there may be two thouſand of them in one *cryſtalline*, from the outermoſt to the centre. Every one of theſe ſcales, he ſaith, he hath diſcovered to be made up of one ſingle fibre, or fineſt thread, wound in a moſt ſtupendous manner, this way and that way, ſo as to run ſeveral courſes, and meet in as many centres, and yet not to interfere or croſs one another in any one place. In *oxen*, *ſheep*, *hogs*, *dogs*, and *cats*, the thread ſpreads into three ſeveral courſes, and makes as many centres: in *whales* five; but in *hares* and *rabbits* only two. In the whole ſurface of an *ox's cryſtalline*, he reckons there are more than twelve thouſand fibres juxtapoſited. For the right and clear underſtanding of the manner of which admirable piece of mechaniſm, I ſhall refer to his cuts and deſcriptions in *Philoſ. Tranſ.* No. 165, and 193. The truth hereof I have heard ſome ingenious men queſtion; but it is what I myſelf have ſeen, and can ſhew to any body, with the help of a good microſcope.

ſerve to be taken notice of in the firſt place, their *medullary* part (*ff*) terminating in the brain itſelf, the teguments propagated from the *meninges*, and terminating in the coats of the eye, and their commodious inſertions into the ball of the eye, in ſome directly oppoſite to the pupil of the eye, in others obliquely towards one ſide (*gg*). But moſt of theſe things have been treated of, and the convevience hereof ſet forth by others that have written of God's works. I ſhall therefore take notice only of one wiſe proviſion the Creator hath made about the motion of the eye, by uniting into one the

(*ff*) *S. Malpighi* obſerved the middle of the *optic nerve* of the *ſword-fiſh*, to be nothing elſe but a large membrane, folded according to its length in many doubles, almoſt like a fan, and inveſted by the *dura mater*; whereas in land-animals it is a bundle of fibres. Vide *Philoſ. Tranſ.* No. 27.

(*gg*) *Certiſſimum eſt, quòd in omnibus oculis humanis (quos ſaltem mihi diſſecare contigit) nervus opticus pupillæ è diametro opponitur, &c.*—" It is very certain, that in the human eye, (at leaſt in all ſuch as I have happened to diſſect,) the optic nerve is placed directly oppoſite to the diameter of the pupil."—Ita *Willis de Anim. de Brut.* p. 1. c. 15.

Nervi optici in nobis, item in cane, fele, (& in cæteris forſan animalibus calidis,) ad fundum oculi delati pupillæ regioni proſpiciunt, dum interim in aliis quadrupedibus, uti etiam in piſcibus & volucribus, obliquè ſemper tunicæ ſclerotidi inſeruntur.—" The optic nerve, in the human ſpecies, and likewiſe in the dog and the cat, (perhaps too in other animals of a warm habit,) is placed at the bottom of the eye and directly fronting the pupil. But in the reſt of the quadrupeds, and in fiſhes and birds, it is always obliquely inſerted in the *tunica ſclerotis*."—Unde, *Willis Ib.* c. 7. ſect. 11.

third

third pair of nerves, called the *motory nerves* (*hh*), each of which fending its branches into each mufcle of each eye, would caufe a diftortion in the eyes; but being united into one, near their infertion into the brain, do thereby caufe both eyes to have the fame motion; fo that when one eye is moved this way and that way, to this and that object, the other eye is turned the fame way alfo.

Thus from this tranfient and flight view (I may call it) of the parts of the eye, it appears what an admirable Artift was the contriver thereof. And now in the

Seventh and laft place, let us confider what provifion this admirable Artift hath made for the *guard* and *fecurity* of this fo well formed organ (*ii*).

And

(*hh*) *This pair is united at its rife; whence is commonly drawn a reafon why one eye being moved towards an object, the other is directed alfo to the fame.* Gibfon's Anat. *book* iii. *chap.* 11. So *Bartholine Anat.* lib. 3. c. 2.

(*ii*) Among all the other fecurity the eye hath, we may reckon the reparation of the *aqueous humour*; by which means the eye when wounded, and that in all appearance very dangeroufly too, doth often recover its fight: of which *Lern. Verzafcha* gives divers examples ancient and modern. One is from *Galen*, of a boy fo wounded, that the *cornea* fell, and became flaccid, but yet he recovered his fight. Other fuch like inftances alfo he gives from *Realdus Columbus*, *Rhodius*, and *Tulpius*; and one that he cured himfelf, in thefe words; *Ego in nobiliffimi viri filiolâ fimilem cafum obfervavi: hæc dum levibus de caufis cum fratre altercaret, ifte iracundiâ percitus cultellum fcriptorium apprehendit, & fororis oculo vulnus infligit, inde humor aqueus effluxit.*

M 3 *Vocatus*

And here we ſhall find the guard equivalent to the uſe and excellency of the part. The whole organ fortified and fenced with ſtrong, compact bones, lodged in a ſtrong, well made ſocket, and the eye it-

Vocatus præſentem chirurgum juſſi ſequens collyrium anodynum & exſiccans tepidè ſæpiùs admovere. ℞ *aq. plantag.* ℥ iv. *Roſar. Sanicul. Euphraſ.* ana *Trochiſc. alb. Rhaſ. cum opio* ℈ij. *tutiæ pp.* ℈ j. *croci orient.* ℈ ß. M. *Hoc collyrium inflammationem compeſcuit, vulnus ſiccavit & ſanavit. Hinc poſt aliquot menſes humor aqueus ſuccrevit. Nam viſus, ſed debilior, cum ſummo parentum gaudio redivit.*—" A ſimilar caſe occurred to myſelf of a nobleman's daughter, who in a trifling quarrel with her brother, was wounded by him in the eye with a pen-knife, ſo that the aqueous humour ran out. Being called to her aſſiſtance, I ordered the ſurgeon who was preſent to apply warm, and frequently to the eye, the following anodyne and exſiccating collyrium, &c.—This reduced the inflammation, and dried and healed the wound. From that time the aqueous humour was renewed in a few months; and to the great joy of her parents, her ſight was reſtored, though ſomewhat weaker than before."—*B. Verzaſchæ Obſerv. Medicæ. Obſ.* 14.

Another cure of this kind was experimented by Dr. *Daniel Major*, upon a gooſe, *ann.* 1670, the *aqueous humour* of both whoſe eyes they let out, ſo that the eyes fell, and the gooſe became quite blind: but without the uſe of any medicine, in about two days time, Nature repaired the watery humour again, the eyes returned to their former turgency, and the gooſe was in a week after produced, ſeeing, before twenty-eight or thirty ſpectators. *Ephem. Germ. T.* 1. *Add. ad. Obſ.* 117.

From the ſame cauſe, I doubt not, it was that the eye of a gentleman's daughter, and thoſe of a cock, when wounded, ſo that the *cornea* ſunk, were reſtored by a *Lithuanian* chymiſt, that paſſed for a conjurer, by the uſe of a liquor found in *May* in the veſiculæ of *elm.* Of which ſee Mr. *Ray's Catal. Cantab.* in *Ulmus* from *Henr. ab Heers.*

ſelf

ſelf guarded with a nice made cover (*kk*). Its humours, and its inward tunics, are indeed tender, propor-

(*kk*) *Palpebræ, quæ ſunt tegmenta oculorum, molliſſimæ tactu, nè læderent aciem, aptiſſimæ factæ, & ad claudendas pupillas, nè quid incideret, & ad aperiendas; idque providit, ut identidem fieri poſſet cum maximâ celeritate. Munitæque ſunt palpebræ tanquàm vallo pilorum: quibus & apertis oculis, ſi quid incideret, repelleretur, & ſomno conniventibus, cùm oculis ad cernendum non egeremus, ut qui, tanquàm involuti, quieſcerent. Latent prætereà utiliter, & excelſis undique partibus ſepiuntur. Primùm enim ſuperiora ſuperciliis obducta ſudorem à capite, & fronte defluentem repellunt. Genæ deinde ab inferiore parte tutantur ſubjectæ, leviterque eminentes.*—"The eye-lids, which are the coverings of the eyes, are ſoft to the touch that they may not hurt the ſight, and are fitted both for veiling and opening the pupils with the greateſt celerity. They are defended by the eye-laſhes, as by a paliſade which prevents any thing from falling into them while the eyes are open; and cloſing together in ſleep the eye is at reſt under their covering. They are, likewiſe, moſt admirably placed under ſhelter, and are guarded on all ſides by more prominent parts. The upper eye-lids, covered by the eye-brows, are ſcreened from the ſweat falling down from the forehead; the under eye-lids are defended by the cheek bones which riſe higher than their ſurface."—*Cicer. de Nat. Deor.* l. 2. c. 57.

Tully, in the perſon of a *Stoick*, having ſo well accounted for the uſe of the *eye-lids*, I ſhall, for a further manifeſtation of the Creator's contrivance and ſtructure of them, take notice of two or three things: 1. They conſiſt of a thin and flexible, but ſtrong ſkin, by which means they the better wipe, clean, and guard the *cornea*: 2. Their edges are fortified with a ſoft *cartilage*, by which means they are not only enabled the better to do their office, but alſo to cloſe and ſhut the better: 3. Out of theſe cartilages grows a paliſade of ſtiff hairs, of great uſe to warn the eye of the invaſion of dangers, to keep off motes, and to ſhut out too exceſſive light, &c. and at the ſame time

proportionate to their tender, curious ufes; but the coats without, are context and callous, firm and

to admit of (through their intervals) a fufficient paffage for objects to approach the eye. And it is remarkable, that thefe hairs grow but to a certain, commodious length, and need no cutting, as many other hairs of the body do: alfo, that their points ftand out of the way, and in the upper lid bend upwards, as they do downwards in the lower lid, whereby they are well adapted to their ufe. From which laft obfervables, we may learn how critical and nice the great Author of Nature hath been, in even the leaft and moft trivial conveniencies belonging to animal bodies; for which reafon I have added it to *Tully*'s remarks. And more might have been added too, as particularly concerning the curious ftructure and lodgment of the *right mufcle*, which opens the eye-lids; and the *orbicularis*, or *circular* one, that fhuts them; the nice *apparatus* of glands that keep the eye moift, and ferve for *tears*; together with the reafon why man alone, who is a focial animal, doth exhibit his focial affections by fuch outward tokens as *tears*; the *nerves* alfo, and other organs acting in this miniftry. I might alfo fpeak of the paffages for difcharging the fuperfluous moifture of the eyes through the noftrils, and much more of the like kind. But it would take up too much room in thefe notes; and therefore it fhall fuffice to give only fuch hints as may create a fufpicion of a noble œconomy and contrivance in this (I had almoft faid) leaft confiderable part of the eye. But for particulars I fhall refer to the anatomifts; and for fome of thefe things, particularly to Dr. *Willis's Cereb. Anat.* and *de Anim. Brut.* and Mr. *Cowper*'s elegant cuts in the 11th *Tab.* of his *Anatomy*.

To the eye-lids we may add another guard afforded the eyes of moft quadrupeds, birds, and fifhes, by the *nictitating-membrane*, which Dr. *Willis* gives this account of: *Plurimis* [animalibus] *quibus mufculus fufpenforius adeft* (which limitation he needed not to have added) *etiam alter membranofus conceditur, qui juxta interiorem oculi canthum fitus, quando elevatur, oculi globum ferè totum obtegit.*

and ſtrong. And in ſome animals, particularly birds *(ll)*, ſome part of thoſe tunicles have the nature and hardneſs of bone or horn.

But for animals, whoſe eyes, like the reſt of their body, are tender, and without the guard of

tegit. Hujus uſus eſſe videtur, ut cum beſtiæ inter gramina, &c. capita ſua propter victum capeſſendum demergunt, hic muſculus oculi pupillam, nè à ſtipularum incurſu feriatur, oculit, munitque.—" In moſt animals which have the ſuſpenſory muſcle, there is likewiſe a membranous muſcle which adjoins to the inner corner of the eye, and when it is raiſed up, covers almoſt the whole ball of the eye; the uſe of which ſeems to be, that when the animals lower their heads in ſearch of food among graſs, buſhes, &c. this muſcle covers and defends the pupil of the eye againſt ſharp pointed ſtraws, and whatever might hurt it."—*De Anim. Brut.* p. 1. c. 15.

This membrane man hath not, he having little occaſion to thruſt his head into ſuch places of annoyance as beaſts and other animals; or if he hath, he can defend his eyes with his hands. But birds (who frequent trees and buſhes) and quadrupeds, (hedges, and long graſs,) and who have no part ready, like the hand, to fence off annoyances; theſe, I ſay, have this incomparable proviſion made for the ſafety of their eyes. And for fiſhes, as they are deſtitute of eye-lids, becauſe in the waters there is no occaſion for a defenſative againſt duſt and motes, offenſive to the eyes of land-animals, nor to moiſten and wipe the eyes, as the eye-lids do, ſo the *nictitating-membrane* is an abundant proviſion for all their occaſions, without the addition of the eye-lids.

And now, if we reflect, are theſe the works of any thing but a wiſe and indulgent Agent?

(*ll*) Although the hardneſs and firmneſs of the *adnata*, or *ſclerotica* in birds, is a good guard to their eyes, yet I do not think it is made thus, ſo much for a defence, as to miniſter to the lengthening and ſhortening the eye, mentioned before in *note* (*cc*).

bones;

bones; there nature hath provided for this neceſſary and tender ſenſe, a wonderful kind of guard, by endowing the creature with a faculty of withdrawing its eyes into its head (*mm*), and lodging them in the ſame ſafety with the body.

Thus have I ſurveyed this firſt ſenſe of animals, I may ſay in a curſory, not accurate, ſtrict manner, conſidering the prodigious workmanſhip thereof; but ſo, as abundantly to demonſtrate it to be the contrivance, the work of no leſs a being than the infinitely wiſe, potent, and indulgent Creator (*nn*). For none leſs could compoſe ſo admirable an organ, ſo adapt all its parts, ſo adjuſt it to all occaſions, ſo nicely provide for every uſe, and for every emergency: in a word, none leſs than God could,

(*mm*) *Cochleis oculorum vicem cornicula bina prætentu implent.*—"Two little horns ſtretched out are the eyes of the ſnails."—*Plin. Nat. Hiſt.* l. 11. c. 37. See more of the eyes of *ſnails* before in *note* (*k*); and in *note* (*l*), I ſaid that I ſuſpected *moles* alſo might thruſt out, or withdraw their eyes more or leſs within the hair or ſkin.

(*nn*) The diligent *Sturmius* was fully perſuaded there could not be any ſpeculative atheiſm in any one that ſhould well ſurvey the eye. *Nobis*, ſaith he, *fuit perſuaſiſſimum, atheiſmum, quem vocant ſpeculativum, h. e. obfirmatam de Deitate in univerſo nullâ perſuaſionem, habere locum aut inveniri non poſſe in eo homine, qui vel unius corporis organici, & ſpeciatim oculi fabricam attento animo aſpexerit.*—"I am thoroughly convinced that what is called ſpeculative atheiſm, or a firm perſuaſion of the non-exiſtence of a Deity, was never found in any man who had attentively conſidered the ſtructure of any organized body, more eſpecially that of the eye."—*Sturm. Exerc. Acad.* 9. *De Viſ. Organ. & Rat. in Epilogo.*

I ſay,

I ſay, thus contrive, order, and provide an organ, as magnificent and curious as the ſenſe is uſeful; a ſenſe without which, as all the animal world would be in perpetual darkneſs, ſo it would labour under perpetual inconveniencies, be expoſed to perpetual harms, and ſuffer perpetual wants and diſtreſſes. But now by this admirable ſenſe, the great God, who hath placed us in this world, hath as well provided for our comfortable reſidence in it; enabled us to ſee and chuſe wholeſome, yea, delicate food; to provide ourſelves uſeful, yea, gaudy cloathing, and commodious places of habitation and retreat. We can now diſpatch our affairs with alacrity and pleaſure, go here and there as our occaſions call us. We can, if need be, ranſack the whole globe, penetrate into the bowels of the earth, deſcend to the bottom of the deep, travel to the fartheſt regions of this world, to acquire wealth, to encreaſe our knowledge, or even only to pleaſe our eye and fancy. We can now look about us, diſcern and ſhun the precipices and dangers which every where encloſe us, and would deſtroy us. And thoſe glorious objects which fill the heavens and the earth, thoſe admirable works of God which every where ſurround us, and which would be as nothing to us without being ſeen, do by means of this noble ſenſe preſent their glories to us (*oo*), and fill us with admiration and

(*oo*) The glorious landſcapes, and other objects that preſent themſelves to the eye, are manifeſtly painted on the *retina*, and that not erect, but inverted as the laws of optics require; and is manifeſt

and pleaſure. But I need not expatiate in the uſefulneſs and praiſes of this ſenſe, which we receive the

manifeſt to the eye from monſieur *Cartes*'s experiment, of laying bare the vitreous humour on the back part of the eye, and clapping over it a bit of white paper, or the ſkin of an egg; and then placing the fore part of the eye to the hole of the window of a darkened room. By which means we have a pretty landſcape of the objects abroad invertedly painted on the paper, on the back of the eye. But now the queſtion is, How in this caſe the eye comes to ſee the objects erect? Monſieur *Cartes*'s anſwer is, *Notitia illius ex nullâ imagine pendet, nec ex ullâ actione ab objectis veniente, ſed ex ſolo ſitu exiguarum partium cerebri, è quibus nervi expullulant.—E. g. cogitandum in oculo—ſitum capillamenti nervi optici—reſpondere ad alium quendam partis cerebri—qui facit ut anima ſingula loca cognoſcat, quæ jacent in rectâ, aut quaſi rectâ lineâ; ut ita mirari non debeamus corpora in naturali ſitu videri, quamvis imago in oculo delineata contrarium habeat.*—"The knowledge of the upright ſituation of objects does not depend on any picture, or any thing proceeding from the objects, but ſolely on the ſituation of the minute parts of the brain from which the nerves ſpring out. For example; we may imagine that the ſmall threads of the optic nerve correſpond with ſome oppoſite part of the brain, ſo that the mind perceives thoſe objects erect, though the picture is reverſed."—*Dioptr.* c. 6. But our moſt ingenious Mr. *Molyneux* anſwereth thus: *The eye is only the organ or inſtrument, it is the ſoul that ſees by means of the eye. To enquire then how the ſoul perceives the object erect, by an inverted image, is to enquire into the ſoul's faculties. But erect and inverted are only terms of relation to up and down; or farther from, or nigher to the centre of the earth, in parts of the ſame thing. But the eye or viſive faculty takes no notice of the internal poſture of its own parts, but uſeth them as an inſtrument only, contrived by Nature for the exerciſe of ſuch a faculty. Let us imagine, that the eye* (on its lower part) *receives an impulſe* [by a ray from the upper part of the object], *muſt not the viſive faculty be neceſſarily directed hereby to conſider this ſtroke as coming from the top rather than the bottom* [of

the benefit of every moment, and the want, or any defect of which, we lament among our greateſt miſfortunes.

Leaving then this ſenſe, I ſhall proceed to the other four, but more briefly treat of them, by reaſon we have ſo ample a ſpecimen of the divine art in the laſt, and may preſume that the ſame is exerted in all as well as one. For a demonſtration of which, let us in the next place carry our ſcrutiny to the ſenſe of *hearing*.

[of the object], *and conſequently be directed to conclude it the repreſentation of the top? Hereof we may be ſatisfied, by ſuppoſing a man ſtanding on his head. For here, though the upper parts of objects are painted on the upper parts of the eye, yet the objects are judged to be erect. What is ſaid of erect and reverſe, may be underſtood of ſiniſter and dexter.* Molyneux's Dioptr. Nov. part i. prop. 28.

CHAP. III.

Of the Senſe of Hearing.

CONCERNING the ſenſe of *hearing*, I ſhall take notice of two things, the organ, the *ear*; and its object, *ſound*.

I. For the organ, the *ear*; I ſhall paſs by its convenient number of being double, which (as in the laſt ſenſe) ſerves for the commodious hearing every way round us; as alſo a wiſe proviſion for the utter loſs or injury (*a*) of one of the ears. But I ſhall

(*a*) I preſume it will not be ungrateful to take notice here of the admirable, as well as uſeful ſagacity of ſome deaf perſons, that have learned to ſupply their want of *hearing* by underſtanding what is ſaid by the motion of the lips. My very ingenious friend Mr. *Waller*, R. S. Secr. gives this account: *There live now, and have from their birth, in our town, a man and his ſiſter, each about fifty years old, neither of which have the leaſt ſenſe of* hearing,—*yet both of theſe know, by the motion of the lips only, whatever is ſaid to them, and will anſwer pertinently to the queſtion propoſed to them.—The mother told me they could hear very well, and ſpeak when they were children, but both loſt that ſenſe afterwards, which makes them retain their ſpeech; though that, to perſons not uſed to them, is a little uncouth and odd, but intelligible enough.* Philoſoph. Tranſ. No. 312.

Such another inſtance is that of Mr. *Goddy*, miniſter of St. *Gervais* in *Geneva*, his daughter. *She is now about ſixteen years old. Her nurſe had an extraordinary thickneſs of* hearing; *at a year old, the child ſpake all thoſe little words that children begin to ſpeak at that age. At two years old, they perceived ſhe had loſt her* hearing,

I ſhall a little inſiſt upon its ſituation, and its admirable fabrick and parts.

1. It is ſituated in the moſt convenient part of the body, (like as I ſaid the eye is,) in a part near the common ſenſory in the brain, to give the more ſpeedy information; in a part where it can be beſt guarded, and where it is moſt free from annoyances and harms itſelf, and where it gives the leaſt annoyance and hindrance to the exerciſes of any other part; in a part appropriated to the peculiar uſe of the principal ſenſes, in the moſt lofty, eminent part of the body, where it can perceive the moſt objects, and receive the greateſt information: And laſtly, in a part in the neighbourhood of its ſiſter ſenſe the eye, with whom it hath peculiar and admirable communication by its nerves, as I intend to ſhew in its proper place. In reſpect then of its ſituation and place in the body, this ſenſe is well deſigned and

hearing, *and was ſo deaf, that ever ſince, though ſhe hears great noiſes, yet ſhe hears nothing that one can ſpeak to her. But by obſerving the motions of the mouth and lips of others, ſhe hath acquired ſo many words, that out of theſe ſhe hath formed a ſort of jargon, in which ſhe can hold converſation whole days with thoſe that can ſpeak her own language. I could underſtand ſome of her words, but could not comprehend a period, for it ſeemed to be but a confuſed noiſe. She knows nothing that is ſaid to her, unleſs ſhe ſeeth the motion of their mouths that ſpeak to her; ſo that in the night, when it is neceſſary to ſpeak to her, they muſt light a candle. Only one thing appeared the ſtrangeſt part of the whole narration: ſhe hath a ſiſter, with whom ſhe hath practiſed her language more than with any other: and in the night, by laying her hand on her ſiſter's mouth, ſhe can perceive by that what ſhe ſaith, and ſo can diſcourſe with her in the night.* Biſhop *Burnet*'s Let. 4. p. 248.

contrived,

contrived, and may ſo far be accounted the work of ſome admirable artiſt. But,

2. If we ſurvey its fabric and parts, it will appear to be an admirable piece of the divine wiſdom, art, and power. For the manifeſtation of which, let us diſtinctly ſurvey the outward and the inward part of this curious organ.

1. For the *outward ear:* if we obſerve its ſtructure in all kinds of animals, it muſt needs be acknowledged to be admirably artificial, it being ſo nicely prepared, and adjuſted to the peculiar occaſions of each reſpective animal. In man (*b*), it is of

(*b*) I cannot but admire that our moſt eminent modern anatomiſts ſhould not agree, whether there be any muſcles in the outward ear of man or not. Dr. *Keil* ſaith there are two; Dr. *Drake* the ſame number; and Dr. *Gibſon* makes them to be four. So alſo doth monſieur *Dionis*, and ſo did the ancient anatomiſts: but Dr. *Schelhammer* expreſsly denies there are any, and ſaith, *Seduxit autem reliquos brutorum anatome, in quorum pleriſque tales muſculi plures inveniuntur; putârunt autem fortaſſis ignominioſum homini, ſi non & his inſtructus eſſet, & minùs inde perfectum animal fore.*—"Others are led into a miſtake from the diſſection of brutes, in moſt of which we find many ſuch muſcles, and they have perhaps thought it derogatory to man to want ſuch muſcles; as if he were on that account a leſs perfect animal."—*Schel. de Auditu*, p. 1. c. 1. ſect. 7. But *Valſalva*, who wrote very lately, and is very accurate in his ſurvey of the ear, ſaith, *Muſculi auriculæ poſteriores quandoque quatuor, quandoque duo; ſed ut plurimùm tres adnotantur; & quando ſolùm duo ſe manifeſtant, tunc unus ex illis duplicato tendine versùs concham deferri ſolet. Horum muſculorum in numero varietatem non ſolùm in diverſis; verum etiam in eodem ſubjecto quandoque vidi.—Ex quibus differentiis ſubortæ ſunt auctorum diſcrepantiæ in horum muſculorum numero, & ſitu: quod non eveniſſet, ſi pluries in diverſis corporibus iidem muſculi quæſiti*

of a form proper for the erect posture of his body. In birds, of a form proper for flight; not protuberant, becaufe that would obftruct their progrefs, but clofe and covered, to afford the eafier paffage through the air. In quadrupeds, its form is agreeable to the pofture, and flower motion of their bodies; and in thefe too, various, according to their various occafions. In fome large, erect, and open, to hear the leaft approaches of dangers (*c*), in others covered, to keep out noxious bodies. In the fubterraneous quadrupeds, who are forced to mine and dig for their food and habitation, as a protuberant ear, like that of other quadrupeds, would obftruct their labours, and be apt to be torn and injured; fo they have the contrary (*d*), their

fiti effent. Ant. Mar. *Valfalva de Aur. Human.* c. 1. fect. 6. But Dr. *Drake* thinks fome of *Valfalva*'s mufcles the product of fancy. Mr. *Cowper* makes them to be three, one *attollent*, and two *retrahent mufcles.* See *Anat.* Tab. 12.

(*c*) *Inter cætera* [animalia aurita] *maximè admirabilis eft auris leporinæ fabrica, quod cùm timidiffimum animal fit, & prorfus inerme, Natura id tum auditu acutiffimo, tanquam hoftium exploratore ad perfentienda pericula, tum pedibus ceu armis ad currendum aptis muniviffe videtur.*—" Among the other animals, the hare's ear is of the moft admirable fabric; for being a moft timid creature, and altogether unarmed, Nature has given her a wonderful acutenefs of hearing for the difcovery of her enemies, and great fwiftnefs of foot as a defence againft them."—*A. Kircher*'s Phonurg. l. 1. fect. 7. Technaf. 2.

(*d*) *Moles* have no protuberant ear, but only a round hole between the neck and fhoulder; which fituation of it, together with the thick, fhort fur that covers it, is a fufficient defenfative againft external annoyances. The *meatus auditorius* is long,

 round,

their ears ſhort, lodged deep and backward in their head, and paſſing to the under part thereof, and all

round, and cartilaginous, reaching to the under part of the ſkull. Round the inſide runs a little ridge, reſembling two threads of a ſcrew; at the bottom whereof is a pretty inlet leading to the drum, made, on one ſide, with the aforeſaid cochleous ridge, and on the other, with a ſmall cartilage. I obſerved there was *cerumen* in the *meatus*.

As to the *inner ear*, it is ſomewhat ſingular, and different from that of the other quadrupeds, and much more from birds, although I have met with ſome authors that make it agreeing with that of birds. There are three ſmall bones only (all hollow) by which the *drum* (to uſe the old appellation) or the *membrana tympani* (as others call it) acteth upon the *auditory nerve*. The firſt is the *malleus*, which hath two proceſſes nearly of equal length; the longer of which is braced to the *membrani tympani*, the ſhorter to the ſide of the *drum* or *os petroſum*; the back part of it reſembles the head and ſtalk of a ſmall *muſhroom*, ſuch as are uſually pickled. On the back of the *malleus* lies the next ſmall bone, which may be called the *incus*, long, and without any proceſs, having ſomewhat the form of the ſhort ſcoop wherewith watermen throw the water out of their wherries. To the end of this the third and laſt ſmall bone is tacked by a very tender brace. This little bone bears the office of the *ſtapes*, but is only forked without any baſe. One of theſe forks is at one *feneſtra*, or *foramen*, the other at another; in which *feneſtræ* I apprehend the forks are tacked to the auditory nerve. Theſe *feneſtræ* (equivalent to the *feneſtra ovalis*, and *rotunda* in others) are the inlets into the *cochlea* and *canales ſemicirculares*, in which the *auditory nerve* lieth. The *ſemicircular canales* lie at a diſtance from the *drum*, and are not lodged (as in other animals) in a ſtrong, thick, body of bone, but are thruſt out, within the ſkull, making an *antrum*, with an handſome *arch* leading into it, into which a part of the brain enters.

One leg of the *malleus* being faſtened to the *membrana tympani*, and the *incus* to the back of the *malleus*, and the top of that to the top of the *ſtapes*, and the forks or branches of the *ſtapes* to the

all ſufficiently fenced and guarded. And as for inſects, reptiles, and the inhabitants of the waters, if they enjoy this ſenſe, (as there is great reaſon to think they do,) it may probably be lodged commodiouſly under the ſame ſecurity and guard, as the ſmelling or ſome other ſenſe is.

And moreover, as the form of this organ is various in various animals, ſo in each of them its ſtructure is very curious and obſervable, being in all admirably contrived to collect the wandering, circumambient impreſſions, and undulations of ſound, and to convey them to the ſenſory within. If I ſhould run over the ſeveral *genera* of animals, we might find a notable proſpect of the handy-work of God (*e*), even in this ſo inconſiderable a part

the *auditory nerve*, I obſerved that whenever I moved the membrane, all the little bones were at the ſame time moved, and conſequently the *auditory nerve* thereby affected alſo.

I hope the reader will excuſe me for being ſo particular in this organ only of the *mole*, a deſpiſed creature, but as notable an example of *God*'s work, as its life is different from that of other quadrupeds; for which reaſon it partly is that I have enlarged on this part differing from that of others, and which nobody that I know of, hath taken much notice of, and which is not diſcoverable without great patience and application; and partly becauſe by comparing theſe obſervations with *book* vii. *chap.* 2. *note* (*d*), we may judge how the ſenſe of hearing is performed.

(*e*) *Among many varieties, both in the inner and outer ear, thoſe which appear in the paſſage into the rock-bone, are remarkable. For in an* owl, *that perches on a tree or beam, and hearkens after the prey beneath her, it is produced farther out above than it is below, for the better reception of the leaſt ſound. But in a* fox, *that ſcouteth underneath the prey at rooſt, it is for the ſame reaſon produced farther out below,*

part of animals. But I ſhall only carry my ſurvey to that of man. And here the firſt thing that offereth itſelf to our view, is the *helix*, with its tortuous cavities, made to ſtop, and collect the ſonorous undulations, to give them a gentle circulation and refraction, and ſo convey them to the *concha*, or larger and more capacious round cell at the entrance of the ear. And to bridle the evagation of the ſound, when arrived ſo far, but withal not to make a confuſion thereof, by any diſagreeable repercuſſions, we may take notice of a very curious proviſion in thoſe little protuberances called the *tragus* and *antitragus* of the outward ear, of a commodious form and texture (*f*), and conveniently lodged for this uſe. The great convenience and benefit of this form and contrivance of the outward ear, is ſufficiently manifeſt by the want thereof, which cauſeth a *confuſion in the hearing, with a certain murmur, or ſwooing like the fall of waters* (*g*).

Another

below. In a pole-cat, *which hearkens ſtrait forward, it is produced behind, for the taking of a forward ſound. Whereas in a* hare, *which is very quick of hearing, and thinks of nothing but being purſued, it is ſupplied with a bony tube, which, as a natural otocouſtic, is ſo directed backward, as to receive the ſmalleſt and moſt diſtant ſound that comes behind her.* Grew's Coſmolog. Sacr. *lib.* 1. *c.* 5. *ſect.* 6.

(*f*) The texture of the *tragus* and *antitragus* is ſofter than that of the *helix*, which ſerveth gently to blunt, not forcibly to repel, the ſound in the *concha*.

(*g*) Dr. *Gibſon*'s Anatomy, *chap.* 22. *book* iii.

Thoſe whoſe ears are cut off have but a confuſed way of hearing, and are obliged either to form a cavity round the ear with their own

hands,

Another wiſe proviſion of the Creator, is in the ſubſtance of the outward ear, which is cartilaginous, the fitteſt for this place. For (as an ingenious anatomiſt (*h*) obſerves) "If it had been bone, "it would have been troubleſome, and might by "many accidents have been broken off: if fleſh, "it would have been ſubject to contuſion." But indeed a worſe conſequence than this would have enſued from ſuch a ſoftneſs as that of fleſh, and that is, it would neither have remained expanded, neither would it ſo kindly receive and circulate the ſounds, but abſorb, retard, or blunt their progreſs into the inward organ. But being hard, and curiouſly ſmooth and tortuous, ſounds find an eaſy paſſage, with a regular volutation and refraction: as in a well-built arch, grotto, or muſical inſtrument, which magnify and meliorate ſounds; and ſome of which convey even a whiſper to a large diſtance (*i*): but from the outward, let us carry our ſurvey,

2. To

hands, or elſe to make uſe of a horn, and apply the end of it to the inner cavity of the ear, in order to receive the agitated air. 'Tis likewiſe obſerved, that thoſe whoſe ears jut out, hear better than flat-eared perſons. Monſieur *Dionis*'s Anat. Demonſtr. 8.

(*h*) *Gibſ.* Ibid.

(*i*) It would fatigue the reader to reckon up the places famed for the conveyance of whiſpers, ſuch as the priſon of *Dionyſius* at *Syracuſe*, which is ſaid to increaſe a whiſper to a noiſe; the clapping one's hands to the ſound of a cannon, *&c.*; or the *aquæducts* of *Claudius*, which carry a voice ſixteen miles, and many others both ancient and modern. If the reader hath a mind to be entertained in this way, he may find enough in *Kircher's Phonurgia.* But it may not be irkſome to mention one or

two

2. To this inward part of this admirable organ. And here we find the moſt curious and artful proviſion for every emergency and occaſion. The *auditory paſſage*, in the firſt place, curiouſly tunnelled, and artfully turned, to give ſounds an eaſy paſſage, as well as a gentle circulation and refraction (ſee plate D. fig. 3.); but withal, ſo as to prevent their too furious ruſhing in, and aſſaulting the more tender parts within.

And foraſmuch as it is neceſſary that this paſſage ſhould be always open, to be upon the watch (*k*); therefore

two of our own in *England*. Among which, one of the moſt famed is the *whiſpering-place* in *Glouceſter cathedral*, which is no other than a gallery above the eaſt-end of the choir, leading from one ſide thereof to the other. It conſiſteth (if I miſtake not) of five angles, and ſix ſides, the middlemoſt of which is a naked, uncovered window, looking into a chapel behind it. I gueſs the two whiſperers ſtand at about twenty-five yards diſtance from one another. But the *dome* of *St. Paul's*, *London*, is a more conſiderable *whiſpering-place*, where the ticking of a watch (when no noiſe is in the ſtreets) may be heard from ſide to ſide; yea, a whiſper may be ſent all round the *dome*. And not only in the gallery below, but above, upon the ſcaffold, I tried, and found that a whiſper would be carried over one's head round the top of the arch, notwithſtanding there is a large opening in the middle of it, into the upper part of the *dome*.

(*k*) *Auditus autem ſemper patet: ejus enim ſenſu etiam dormientes egemus: A quo cùm ſonus eſt acceptus, etiam è ſomno excitamur. Flexuoſum iter habet, nè quid intrare poſſit, ſi ſimplex, & directum, pateret; proviſum etiam, ut ſiqua minima beſtiola conaretur irrumpere, in ſordibus aurium, tanquàm in viſco, inhæreſceret.*—" The ſenſe of hearing is always awake; for even while aſleep we ſtand in need of that ſenſe; whence, when any ſound is received by the ear, we are rouſed from ſleep. The ear has a winding paſſage to prevent

therefore to prevent the invaſion of noxious inſects, or other animals, (who are apt to make their retreat in every little hole,) Nature hath ſecured this paſſage (*l*), with a bitter nauſeous excrement (*m*), afforded

prevent any ſubſtance from getting in, which might happen if it were ſtraight. It is likewiſe furniſhed with wax, in which any inſect attempting to penetrate into the ear, is intercepted and ſticks faſt."—*Cicer. de Nat. Deor.* l. 2. c. 57.

It deſerves a particular remark here, that in infants in the womb, and newly born, the *meatus auditorius* is ſhut up very cloſely, partly by the conſtriction of the paſſage, and partly by a glutinous ſubſtance, whereby the *tympanum* is guarded againſt the water in the *ſecundine*, and againſt the injuries of the air as ſoon as the infant is born.

(*l*) It is remarkable, that in moſt, if not all animals, whoſe ears are tunnelled, or where the *meatus auditorius* is long enough to afford harbour to *ear-wigs*, or other inſects; that, I ſay, in the ears of ſuch, *ear-wax* is conſtantly to be found. But in birds, whoſe ears are covered with feathers, and where the *tympanum* lies but a little way within the ſkull, no *ear-wax* is found, becauſe none is neceſſary to the ears ſo well guarded and ſo little tunnelled.

(*m*) The *ear-wax* was thought, by the old anatomiſts, to be an excrement of the brain: *Humor bilioſus à cerebro expurgatus*,—"A bilious humour purged from the brain,"—the *Bartholines* ſay of it, *l.* 3. *c.* 9. But as *Schelhammer* well obſerves, *Nil abſurdius, quàm cerebri excrementum hoc ſtatuere. Nam & ratio nulla ſuadet, ut in cerebro fieri excrementum tale credamus:—neque viæ patent per quas ab eo ſecluſum in meatum auditorium poſſit inde penetrare.*—"There is nothing more abſurd than to ſuppoſe this to be an excrement of the brain; for there is no reaſon to believe that the brain produces any ſuch excrement; nor is there any courſe by which it could find its way from the brain into the auditory paſſage."—As to its taſte, *Caſſerius* gives inſtances of its being ſweet in ſome creatures. But *Schelhammer* ſays, *Ego verò ſemper, eum amaritie aliquid dulcedinis in illo deprehendi.*—

 "I have

afforded from the glands (*n*) appointed for that purpofe.

From hence let us approach the moft inward parts, in which we fhall fee ftrokes of the moft exquifite art. To pafs over the *innate air*, that moft authors talk of (*o*), (becaufe there is no fuch,) the paffage

" I have always found a little fweetnefs along with its bitternefs."—Vide *Schel. de Audit*, p. 1. c. 2. fect. 10. But I could never diftinguifh any fweetnefs in it; but think it infipid mixed with a bitternefs.

(*n*) *Cerumina amara arteriolis exudantia.*—" A bitter waxy fubftance exfuding from the glands."—*Willis de Anim. Brut.* par. 1. c. 14. *In the fkin—are little glands, which furnifh a yellow and bitter humour.* Monfieur *Dionis*'s Dem. 18. An handfome cut of thofe *glandulæ ceruminofæ* is in Dr. *Drake*, from *Valfalva*. See likewife plate D, fig. 3. (7).

Pliny attributes a great virtue to the *ear-wax*: *Morfus hominis inter afperrimos numeratur: medentur fordes ex auribus: ac ne quis miretur, etiam fcorpionum ictibus ferpentiumque ftatim impofitæ.*—" The bite of a man is reckoned extremely dangerous. The cure for it is the ear-wax, and what is more extraordinary, this fubftance will cure even the fting of a fcorpion or ferpent."—*Plin. Nat. Hift.* l. 28. c. 4. And that it hath an healing quality, and may be accounted a good balfam, I myfelf have experienced.

(*o*) That there is fuch a thing as the *innate air*, (talked of much by moft authors on this fubject,) *Schelhammer* very juftly, I think, denies; by reafon there is a paffage into the inner ear from the throat, through which the *innate air* may pafs out, and the outward air enter in. Vide *Par. Alt.* p. 2. c. 1. fect. 10. When by ftopping our breath, and ftraining, we force the external air into the ear, it may be heard rufhing in; and if much be forced in, it may be felt alfo to beat againft the *tympanum*. When the paffage to the throat is by any means ftopped, as by a cold in the head, *&c.* the hearing thereby becomes dull and blunt; by reafon the communication between the outward and inward

paſſage to the palate (*p*), and their uſes, with divers other curious things that might be named; let us ſtop a little at the part containing the reſt, namely, the bone (*q*). The particular texture and hardneſs of

inward air is obſtructed: but when by ſtrong ſwallowing, or ſuch like motion of the throat, the paſſage is opened, we perceive it by a ſudden ſmack or crack, and we immediately hear very clearly; the load of feculent air being at that time diſcharged from the inner ear.

It is a wiſe proviſion, that the paſſage for the air into the ear is from the throat; *Ut non ſtatim quivis aer externus irrumpere queat* (as *Schelhammer* ſaith, *Par. ult. c.* 4. *ſect.* 8.) *ſed nonnihil immutatus, ac temperatus, calore ex medio ventre exſpirante; imò fortaſſis non facilè alius, niſi ex pulmonibus.*—"So that the external air cannot immediately find entrance, but receives a change and temperature from the heat of the body, and muſt, perhaps, be expired from the lungs before it gets into the ear."

(*p*) *Valſalva* hath given us a more accurate deſcription of the *tuba Euſtachiana*, or *paſſage to the palate*, than any other author, to whom I therefore refer, *De Aur. Human.* c. 2. ſect. 16, *&c.*

The chief uſe hereof, he thinks, is to give way to the inner air, upon every motion of the *membrana tympani*, the *malleus*, *incus*, and *ſtapes*. This paſſage, if it be ſhut up, deafneſs enſues: of which he gives two inſtances: one a gentleman, who loſt his hearing by a polypus in the noſe reaching to the *uvula*; the other a yeoman, labouring with an ulcer above the left ſide of the *uvula*; which when he ſtopt with a tent dipped in medicine, he loſt his hearing in the left ear, and recovered it, as ſoon as the tent was out. *Ibid.* c. 5. ſect. 10.

(*q*) Os [petroſum] *ex quo interiores* [labyrinthi] *cavitatum parietes conflati ſunt, album, duriſſimum, necnon maximè compactum. Id autem à Naturâ ita comparatum eſſe videtur, ut materia ætherea ſonorum objectorum impreſſionibus onuſta, dum prædictis impingitur parietibus, nihil aut ſaltem ferè nihil motûs ſui amittat, atque adeò illum qualem ab objectis ſonoris accepit, talem communicet ſpiritui animali contento intra expanſiones rami mollioris nervorum auris.*—"The

of which, above other bones of the body, is very remarkable; whereby it ſerves not only as a ſubſtantial guard to the ſenſory, but alſo to oppoſe the impulſes of the ætherial matter, that there may be no loſs nor confuſion in the ſound; but that it may be convèyed regularly, and entirely to the auditory nerves.

The next part I ſhall take notice of may be that fine membrane called the *tympanum*, or *membrana tympani* (*r*), with its inner membrane (*s*); together with

" The bone called *rock-bone*, of which the interior partitions of the cavities are compoſed, is white, extremely hard, and very much compacted; which ſeems to be ſo formed by Nature, that the air, while impreſſed by ſounds, and ſtriking upon theſe walls or partitions, may loſe ſcarcely any thing of its motion, and thus may communicate to the animal ſpirits contained within the expanſions of the ſofter branch of the nerves of the ear, the ſame impreſſion it has received from the ſonorous objects." —Dr. *Raym. Vieuſſens* of *Montpellier*, in Phil. Tranſ. No. 258.

(*r*) The *tympanum* of the ear, or, as *Valſalva* and the moderns term it, the *membrana tympani*, was taken notice of as early as *Hippocrates*'s time. In birds, it is ſtrained towards the outward parts; in other animals, towards the brain, or inner parts. Monſieur *Dionis* ſaith, *It is not equally faſtened to the whole circumference of the bony circle, in which it is inchaſed; for on the upper ſide it hath a free diſengaged part, by which ſome can give vent to the ſmoke in their mouth.* Demonſtr. 8. That there is ſome paſſage I doubt not, but I queſtion whether Monſieur *Dionis* ever ſaw the diſengaged part he mentions. I have myſelf carefully ſearched divers ſubjects, and do not remember to have ſeen any ſuch paſſage; and I perceive, it eſcaped the diligent *Schelhammer*'s eye. *Valſalva*, alſo, by injecting in through the *tuba Euſtachiana*, could not force any liquor into the *meatus auditorius*: but yet he imagines he found the paſſage out in another place of the

with the four little appendent bones (*t*), and the three inner muſcles to move them, and adjuſt the whole

the drum, in ſome morbid, and one ſound head. *Valſalv. de Aur. Hum.* c. 2. ſect. 8. Mr. *Cowper* alſo affirms there is a paſſage by the upper part of the membrane. *Anat. Ap.* fig. 8.

(*s*) Dr. *Vieuſſens*, before-named, diſcovered a membrane, *tenuiſſimæ raræque admodùm texturæ intra cavitatem tympani,*—"of a very thin and rare texture within the cavity of the tympanum,"—as he deſcribes it. Whoſe uſe he ſaith is, 1. *Occludens labyrinthi januam impedit nè naturalis puriſſimus ac ſubtiliſſimus aer intra cavitates—communicationem—habeat cum aere craſſo.* 2. *Labyrinthi baſin calefacit,* &c. *ubi ſupra.*—"1. By cloſing the entry of the labyrinth it prevents the natural pure and ſubtle air within the cavities, from having any communication with the denſe external air. 2. It warms the bottom of the labyrinth." Probably this double membrane may be ſuch, or after the ſame manner as it is in the *tympanum* of birds: of which ſee my obſervations in *book* vii. *chap.* 2. *note* (*d*).

(*t*) The four little bones being treated of by all that have concerned themſelves about this ſenſe of hearing, ſince their diſcovery, I ſhall take notice of only two things concerning them. 1. The diſcovery of them is owing wholly to the diligence and ſagacity of the latter ages; of which *Schelhammer* gives this account from *Fallopius*: *Hæc oſſicula antiquis anatomicis—ignota fuere; primuſque qui in lucem produxit* [malleum & incudem] *fuit Jac. Carpenſis; primus quoque procul omni dubio anatomicæ artis, quam Veſalius poſteà perfecit, reſtaurator. Tertium* [Stapedem] *invenit ac promulgavit primus Joh. Phil. ab Ingraſſia, Siculus, philoſophus, ac medicus doctiſſimus. Quartum, Thomâ Bartholin. teſte, viro longè celeberrimo, Fran. Sylvio debetur.* Schel. *ubi ſupra*, c. 3. ſect. 9.—"Theſe little bones were unknown to the ancient anatomiſts. The firſt who diſcovered the malleus and incus, was James Carpenſis, the earlieſt reſtorer of the art of anatomy, which was afterwards perfected by Veſalius. The third bone, viz. the *ſtapes*, was firſt found out by Joh. Phil ab Ingraſſia, from Sicily, a learned philoſopher and phyſician. The

whole *compages* to the feveral purpofes of hearing, to hear all manner of founds, loud or languid, harfh or grateful (*u*).

From

The fourth, as Bartholin informs us, was difcovered by the celebrated *Fr. Sylvius.*"—2. Their difference in animals: In *man*, and *quadrupeds*, they are four, curioufly inarticulated with one another; with an external and internal mufcle to draw or work them, in extending or relaxing the *drum*; but in *fowls* the cafe is very different: *His unum offiiculum folùm largita eft Natura, quod collumellam fortè appellaveris: teres enim eft & fubtiliffimum, bafi innitens latiori, rotundæ. Huic adnexa eft cartilago valde mobilis, quæ in tympanum videtur terminari.*—" To thefe Nature has given only one little bone, which we may term columella or the pilafter; for it is taper and flender, refting on a broader and round bafe. To this is joined a very moveable cartilage, which feems to terminate in the *tympanum.*"—*Id. ib.* fect. 8. *In the ears of all the fowl that I could examine, I never found any more than one bone, and a cartilage, making a joint with it, that was eafily moveable. The cartilage had generally an epiphyfe, or two, one on each fide. The bone was very hard and fmall, having at the end of it a broad plate, of the fame fubftance, very thin, upon which it refted, as on its bafis.* Dr. *Al. Moulen* in Phil. Tranf. No. 100.

Thefe are the moft material things I find obferved by others, concerning the ears of fowls, and fome of them hardly, I believe, obferved before. To which I fhall fubjoin fome other things I have myfelf difcovered, that I prefume efcaped the eyes of thofe moft curious and inquifitive anatomifts. Of which the laft cited *book* vii. *chap.* 2. *note* (*d*).

(*u*) *Videtur quòd tympanum auditionis inftrumentum præliminare, & quafi præparatorium fuerit, quod foni impreffionem, five fpecies fenfibiles primo fufcipiens, eas in debitâ proportione, & aptâ conformitate, versùs fenforium, quod adhuc interiùs fitum eft, dirigat: fimili officio fungitur refpectu auditûs, ac tunicæ oculi pupillam conftituentes, refpectu visûs; utræque membranæ fpecies fenfibiles refringunt & quafi emolliunt, eafque fenforio non nifi proportionatas tradunt, cui nudo fi adveniant,*

From this region of the *tympanum*, I might paſs to that of the *labyrinth* (*w*), and therein ſurvey the curious

adveniant, teneriorem ejus craſin facilè lædant, aut obruant. Reverâ tympanum non audit, ſed meliori tutiorique auditioni confert. Si hæc pars deſtruatur, ſenſio adhuc aliquamdiu, redi licèt modo, peragi poſſit; quippe experimento olim in cane facto, &c. Janitoris officio ut tympanum rectè defungi poſſit, expanſum ejus pro datâ occaſione ſtringi, aut relaxari debet, veluti nimirùm Oculi pupilla—Quapropter huic auris tympano, non ſecus ac bellico, machinæ ſive tæniæ quædam apponuntur, quæ ſuperficiem ejus modò tenſiorem, modò laxiorem reddant: hoc enim efficiunt tria oſſicula, cum muſculo, &c.—"The tympanum appears to be, as it were, the preparatory inſtrument of ſound; becauſe receiving firſt the impreſſion of the ſounds, it tranſmits them in due proportion and apt conformity towards the *ſenſorium*, which is placed farther within. It performs a ſimilar office with reſpect to hearing, that the coats of the pupil do with reſpect to ſight. Both membranes refract, and as it were, ſoften the ſenſible impreſſions, and tranſmit them juſtly proportioned to the *ſenſorium*, which would be hurt by their reaching it at once. It is not in fact the *tympanum* which hears; it only contributes to the ſafe tranſmiſſion of the ſounds. Although that part were deſtroyed, there might be ſome ſenſe of hearing, as was proved by an experiment on a dog. In order that the tympanum may rightly perform the office of a porter or janitor to the ear, its expanſe muſt be ſtretched or relaxed as there is occaſion, in the ſame manner as the pupil of the eye: and therefore the tympanum, like the common drum, has certain braces which ſtretch or ſlacken its ſurface; this is effected by three ſmall bones with a muſcle."—*Willis de Anim. Brut.* c. 14.

For this opinion of Dr. *Willis*, Dr. *Schelhammer* is very ſevere upon him, deriding the refractions he ſpeaks of; and therefore ſeriouſly proves that they are the humours, not tunics of the eye, that refract the rays of light; and then jeeringly demandeth, Whether the ſonorous rays are refracted by paſſing through a different medium? Whether the convexity or concavity of the drum collects thoſe rays into a focal point, or ſcatters them? *&c.* And then ſaith,

curious and admirable ſtructure of the *veſtibulum*, the *ſemicircular canals* (*x*), and *cochlea*; particularly the

ſaith, *Ob has rationes à clariſſ-viri, ac de re medicâ præclarè meriti, ſententiâ non poſſumus non eſſe alieniores; in quo uti ingenium admiror, quoties medicamentorum vires, aut morborum cauſas explicat, ſic ubi forum ſuum egreſſus philoſophum agit, ac vel partium uſum, vel chymicarum rerum naturam ſcrutetur, ejus haud ſemel non modò judicium deſidero, verùm aliquando etiam fidem.*—" For theſe reaſons I cannot help differing in opinion from that celebrated man and excellent phyſician; whoſe genius, although I much admire in the explanation of the power of medicines and the cauſes of diſeaſes, yet when he goes out of his proper department, and aſſumes the character of philoſopher in inquiring into the uſes of the parts, or attempting chemical diſcuſſions, I find in him a want of judgment, and ſometimes even of veracity."—This is ſo ſevere and unjuſt a cenſure of our truly famous countryman (a man of known probity) that might deſerve a better anſwer; but I have only time to ſay, that although Dr. *Schelhammer* hath outdone all that wrote before him, in his book *de Auditu*, and ſhewed himſelf a man of learning and induſtry; yet as our countryman wrote more than he, (though perhaps not free from errors too,) ſo he hath manifeſted himſelf to have been as curious and ſagacious an anatomiſt, as great a philoſopher, and as learned and ſkilful a phyſician, as any of his cenſurers, and his reputation for veracity and integrity was no leſs than any of theirs too. But after all this terrible clamour, Dr. *Schelhammer* prejudicately miſtaketh Dr. *Willis*'s meaning, to ſay no worſe. For by *utræque membranæ refringunt*, Dr. *Willis* plainly enough, I think, means no more than a reſtriction of the ingreſs of too many rays; as his following explicatory words manifeſt, viz. *refringunt, & quaſi emolliunt, eaſque ſenſorio non niſi proportionatas tradunt*;—" blunt and, as it were, ſoften the ſenſible impreſſions, and tranſmit them juſtly proportioned to the ſenſorium."—But indeed Dr. *Schelhammer* hath ſhewn himſelf a too rigid cenſor, by making Dr. *Willis* ſay, the *ear-drum* hath ſuch like braces as the *war-drum*, viz. *Quod porrò de machinis ſeu tæniis tympani bellici adducit, dicitque idem in tympano auditorio conſpici, id prorſus falſiſſimum eſt.*

the artificial gyrations, and other ſingular curioſities obſervable in the two latter.

But

eſt.—" Beſides, what he ſays of the braees of the war-drum, affirming that there are the ſame in the tympanum of the ear, is altogether falſe."—I wonder Dr. *Schelhammer* did not alſo charge Dr. *Willis* with making it a porter, ſincc he ſaith in the ſame paragraph, *Janitoris officio*, &c. But Dr. *Willis*'s meaning is plain enough, that the little bones and muſcles of the *ear-drum* do the ſame office in ſtraining and relaxing it, as the braces of the *war-drum* do in that. And conſidering how curious and ſolemn an apparatus there is of bones, muſcles, and joints, all adapted to a ready motion; I am clearly of Dr. *Willis*'s opinion, that one great uſe of the *ear-drum* is for the proportioning ſounds, and that by its extenſion and retraction, it correſponds to all ſounds, loud or languid, as the pupil of the eye doth to ſeveral degrees of light: and that they are no other than ſecondary uſes aſſigned by Dr. *Schelhammer*, as the principal or ſole uſes of keeping out the external colder air, duſt, and other annoyances; but eſpecially that, *Ob ſolius aeris interni potiſſimùm irrumpentis vim, hunc motum tympani ac mallei eſſe conditum, ut cedere primùm, deinde ſibi reſtitui queat*;—" This motion is given to the *tympanum* and *malleus* chiefly on aeeount of the force of the external air in ruſhing into the ear; ſo it is capable of yielding firſt to that force, and then reſtoring itſelf;"—as his words are, P. *ult.* c. 6. ſect. 13.

It was no improbable thought of *Rohault*, *Nos attentos præbere, nil aliud eſt, niſi* tympanum, *ubi ita opus eſt facto, contendere aut laxare, & operam dare ut illud in eâ poſitione intentum ſtet, in quâ tremulum aeris externi motum commodiſſimè excipere poſſit.*—" When we liſten attentively, it is nothing elſe than ſtretching or relaxing the *tympanum*, according to the exigency, and thus keeping it in that ſtate in which it ean moſt conveniently receive the motion of the external air."—*Rob. Phyſ.* p. 1. c. 26. ſect. 48.

The hearing of deaf perſons more eaſily by means of loud noiſes, is another argument of the uſe of the ſtraining or relaxation

tion

But I ſhall not expatiate on theſe recluſe parts; only there is one ſpecial contrivance of the nerves miniſtering

tion of the *tympanum* in hearing. Thus Dr. *Willis* (ubi ſupra) *Accepi olim à viro fide digno, ſe mulierem noviſſe, quæ licèt ſurda fuerit, quouſque tamen intra conclave tympanum pulſaretur, verba quævis clarè audiebat: quare maritus ejus tympaniſtam pro ſervo domeſtico conducebat, ut illius ope, colloquia interdum cum uxore ſuâ haberet. Etiam de alio ſurdaſtro mihi narratum eſt, qui prope campanile degens, quoties unà plures campanæ reſonarent, vocem quamvis facile audire, & non aliàs, potuit.*—"I was informed by a perſon of credit that he knew a woman who was deaf, yet could diſtinctly hear any words that were ſpoken while a drum was beating in the chamber: and that her huſband on that account kept a drummer for his ſervant, that he might thus hold converſations with his wife. I have been told likewiſe of a perſon who was ſomewhat deaf, who, living in the neighbourhood of a belfry, could diſtinctly hear any one ſpeaking, while ſeveral bells were ringing together, but not at any other time."—

Abſciſſo muſculo [proceſſus majoris mallei] *in recenti aure, relaxatur* [tympani membrana.]—"When the muſcle is cut out (the proceſs of the larger *malleus*) in a freſh ear, the membrane of the *tympanum* is ſlackened."—*Valſalv. de Aur. Hum.* c. 2. ſect. 5.

Upon conſidering the great difference in authors' opinions about the uſe of the parts, and manner how hearing is performed, as alſo what a curious proviſion there is made in the ear, by the four little bones, the muſcles, membrane, &c. I was minded (ſince I penned this note) to make inquiry myſelf into this part, and not to rely upon authority. And after a diligent ſearch of various ſubjects, I find we may give as rational and eaſy an account of hearing, as of ſeeing, or any other ſenſe; as I have ſhewn in my laſt cited *note* (*d*), *book* vii. *chap.* 2. with relation to birds. And as to men and beaſts, the caſe is the ſame, but the apparatus more complex and magnificent. For whereas in birds, the *auditory nerve* is affected by the impreſſions made on the *membrane*, by only the intermediacy of the *collumella*;

in

miniſtring to this ſenſe of hearing, which muſt not be paſſed by; and that is, the branches of one of the

in man, it is done by the intervention of the four little bones, with the muſcles acting upon them; his hearing being to be adjuſted to all kinds of ſounds, or impreſſions made upon the *membrana tympani*. Which impreſſions are imparted to the *auditory nerve*, in this manner, *viz.* Firſt they act upon the *membrane* and *malleus*, the *malleus* upon the *incus*, and the *incus* upon the *os orbiculare* and *ſtapes*; and the *ſtapes* upon the *auditory nerve*: for the baſe of the *ſtapes* (the ſame as the *operculum* in birds) not only covers the *feneſtra ovalis*, within which the *auditory nerve* lieth, but hath a part of the *auditory nerve* ſpread upon it too. It is manifeſt that this is the true proceſs of hearing; becauſe if the *membrane* be moved, you may ſee all the bones move at the ſame time, and work the baſe of the *ſtapes* up and down in the *feneſtra ovalis*, as I ſhewed in this chapter, *note* (*d*), concerning the *mole*; and as it may be ſeen in other ears carefully opened, if the parts remain *in ſitu*.

(*w*) I do not confine the *labyrinth* to the *canales ſemicirculares*, or any other part, as the elder anatomiſts ſeem to have done, who by their erroneous and blind deſcriptions ſeem not well to have underſtood theſe parts; but with thoſe much more curious and accurate anatomiſts, Monſieur *de Vernay*, and Dr. *Valſalva*; under the *labyrinth*, I comprehend the *canales ſemicirculares*, and the *cochlea*, together with the intermediate cavity, called by them the *veſtibulum*.

(*x*) In the *ſemicircular canals*, two things deſerve to be noted. 1. That the three canals are of three different ſizes, *major*, *minor*, and *minimus*. 2. Although in different ſubjects, they are frequently different; yet in the ſame ſubject they are conſtantly the ſame. The reaſon of all which, together with their uſes, *Valſalva* ingeniouſly thinks is, that as a part of the tender *auditory nerve* is lodged in theſe canals, ſo they are of three ſizes, the better to ſuit all the variety of tones; ſome of the canals ſuiting ſome, and others, other tones. And although there be ſome difference as to the length and ſize of theſe canals, in different

perſons;

the *auditory nerves* (*y*), ſpread partly to the muſcles of the ear, partly to the eye, partly to the tongue and inſtruments of ſpeech, and inoſculated with the nerves to go to the heart and breaſt. By which means there is an admirable and uſeful conſent between theſe parts of the body; it being natural for moſt animals, upon the hearing any uncouth ſound, to erect their ears, and prepare them

perſons; yet, leſt there ſhould be any diſcord in the auditory organs of one and the ſame man, thoſe canals are always in exact conformity to one another in one and the ſame man. *V. Valſal. ubi ſupr.* c. 3. ſect. 7. and c. 6. ſect. 4. 9.

(*y*) *Hic poſterior nervus extra cranium delatus, in tres ramos dividitur, qui omnes motibus patheticis—inſerviunt. Primus—muſculis auris impenditur. Proculdubio hujus actione efficitur, ut animalia quævis, à ſubito ſoni impulſu, aures, quaſi ſonum nimis citò tranſeuntem captaturas erigant. Ramus alter—verſus utrumque oculi angulum ſurculos emittit: qui muſculis palpebrarum attollentibus inſeruntur; quorum certè munus eſt ad ſubitum ſoni appulſum oculos confeſtim aperire, eoſque velut ad excubias vocare. Tertius—ramus verſus linguæ radicem deſcendens, muſculis ejus & oſſis hyoeideos diſtribuitur, adeòque organa quædam vocis edendæ actuat, &c.*— "This laſt nerve paſſing without the ſkull, is divided into three branches, which are all ſubſervient to ſympathetic motions. The firſt of them is connected with the muſcles of the ear, and by its action all animals, upon any ſudden impulſe of ſound, erect their ears, as if to catch at it while quickly paſſing over them. The ſecond branch ſends out little fibres towards the corner of each eye, which are inſerted in the muſcles that raiſe the eye-lids, and it is certainly their office to open the eyes upon a ſudden impulſe of ſound, and as it were ſummon them to be upon the watch. The third branch, deſcending towards the root of the tongue, is diſtributed in its muſcles and in thoſe of the *os hyoeides*, and ſo actuates ſome of the organs of ſpeech."—*Willis*'s Cereb. Anat. c. 17.

to

Fig. 2.

Fig. 1.

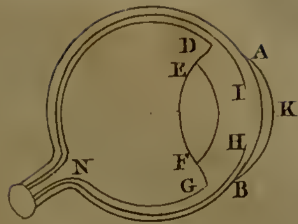

Fig. 4.

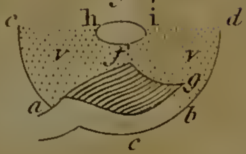

Fig. 3.

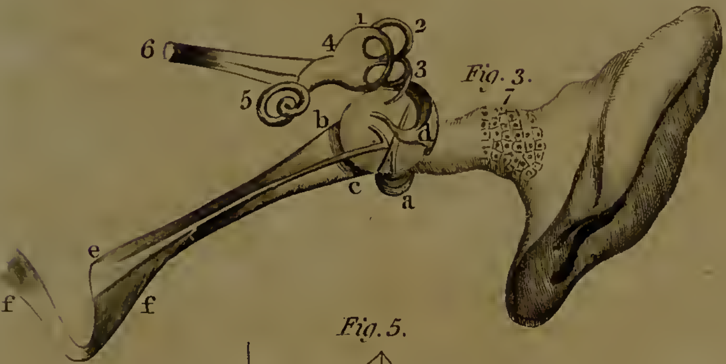

Fig. 5.

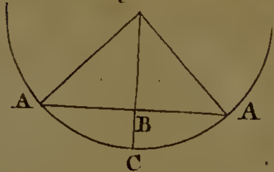

Fig. I. The three concentric circles represent the coats of the Eye The outward called Sclerotica, becomes more convex at AKB, *& forms the Cornea. The middle oval is termed the Uvea, of which the central part being fibrous is termed the Iris, the aperture.* IH *being the pupil. The inward coat where it is attached to the inside of the crystalline humour or lens* EF. *is called the ligamentum ciliare. The cavity* AEBF *is filled with the aqueous humour, and the chamber* DNGFE *is filled with the vitreous humour: At* N *is inserted the optic Nerve, the expansion of which* DNG *is the Retina.*

Fig. 2. Shews the eyeball with its muscles. a *the optic nerve.* b *the musculus Trochlearis.* c *part of the os frontis to which the trochlea or pully is fixed through which* d *the tendon of the trochlearis pafses.* e *Attollens oculi.* f *adductor oculi.* g *abductor oculi.* h. *obliquus inferior.* i *part of the superior maxillary bone to which it is fixed.*

Fig. 3. The interior parts of the Ear. a. *the malleus.* d *the incus.* c *the Membrana tympani.* be. *the Eustachian tube covered by part of* ff. *the musculus circumflexus palati.* 1. 2. 3. *the three Semicircular canals.* 4 *The vestible.* 5. *the Cochlea.* 6 *the portio mollis of the* ? *seventh pair of Nerves.* 7 *The Glands that secrete the Ear wax.*

Fig. 4. Eye of Birds See p. *Fig. 5. See p.*

to catch every ſound; to open their eyes (thoſe conſtant faithful centinels) to ſtand upon their watch; and to be ready with the mouth to call out, or utter what the preſent occaſion ſhall dictate. And accordingly it is very uſual for moſt animals, when ſurpriſed and terrified with any noiſe, preſently to ſhriek and cry out.

But there is beſides this, in man, another great uſe of this nervous commerce between the ear and mouth; and that is, (as one of the beſt authors on this ſubject expreſſeth it (z),) "That the voice "may correſpond with the hearing, and be a kind "of echo thereof, that what is *heard* with *one* of "the two nerves, may be readily expreſſed with "the voice, by the help of the *other*."

Thus much ſhall ſuffice to have ſpoken concerning the organ. Let us,

II. Take notice of the *object* of this admirable ſenſe, namely *ſound*; and ſo conclude this chapter. I ſhall not here enquire into the nature and properties of *ſound*, which is in a great meaſure intricate, and hath puzzled the beſt naturaliſts: neither ſhall I ſhew how this admirable effect of the divine contrivance, may be improved to divers uſes (*aa*) and purpoſes

(z) *Hujuſmodi nervorum conformatio in homine uſum alium inſigniorem præſtat, nempe ut vox, &c.*—"A ſimilar conformation of nerves in the human body has another more remarkable uſe, namely, that the voice may correſpond, &c."—*Willis*, ibid.

(*aa*) Among the uſes to which the wit of man hath employed ſounds, we may reckon the inſtruments uſeful in convocating

purposes in human life; but my business will be to shew that this thing, of so admirable use in the animal

eating assemblies, managing armies, and many other occasions, wherein bells, trumpets, drums, horns, and other sounding instruments are used; the particularities of which it would be tedious to recount: as that the biggest *bell* in *Europe* is reckoned to be at *Erfurt* in *Germany*, which they say may be heard twenty-four miles; with much more to the same purpose. I shall therefore only for a sample take notice of the *speaking-trumpet*; the invention of which is commonly ascribed to our eminent sir *Samuel Morland*; but was more probably *Ath. Kircher*'s; at least he had contrived such an instrument, before sir *Samuel* hit upon his. *Kircher* in his *Phonurg.* saith, The *tromba* published last year in *England*, he had invented twenty-four years before, and published in his *Musurgia*; that *Jac. Albanus Ghibbesius* and *Fr. Eschinardus* ascribe it to him; and that *G. Schottus* testifieth he had such an instrument in his chamber in the *Roman college*, with which he could call to, and receive answers from the porter. And considering how famed *Alexander the Great*'s tube was, which is said might be heard 100 *stadia*, it is somewhat strange that nobody sooner hit upon the invention. Of this *stentorophonic horn* of *Alexander*, there is a figure preserved in the *Vatican*, which for curiosity-sake, I have from *Kircher* represented in Plate L, fig. 6. He saith its diameter was five cubits, and that it was suspended on a supporter.

For the make of the *speaking trumpet*, and the reason why it magnifies sounds, I shall refer to *Kircher*; especially to sir *Samuel Morland's tuba stentorophonica*, published in 1672.

Kircher saith, he took one of these trumpets of fifteen palms length, along with him to the *Mons Eustachianus*, where he convocated 2200 persons to prayers, by means of the unusual sound, at two, three, four, and five *Italian* miles distance. See Plate L, fig. 7.

With these *bellowing-trumpets*, I shall join some *bellowing-caves* for the reader's diversion. *Ol. Magnus* describes a cave in *Finland*, near *Viburg*, called *Smellen*, into which, if a dog, or other living creature be cast, it sends forth so dreadful a sound, that it knocks

animal world, is the work of God. And this will appear, let the ſubject matter of ſounds be what it will; either the atmoſphere (*bb*) in groſs, or the ætherial

knocks down every one near it. For which reaſon they have guarded the cave with high walls, to prevent the miſchiefs of its noiſe. Vide *Ol. Magn. Hiſtor.* l. 11. c. 4. Such another *Peter Martyr* ſaith is in *Hiſpaniola*, which, with a ſmall weight caſt into it, endangers deafneſs at five miles diſtance. And in *Switzerland, Kircher* ſaith, in the *cucumer-mountain* is a pit that ſends out both a dreadful noiſe and a great wind therewith; and that there is a well in his country 3000 palms deep, whoſe ſound is equal to that of a great gun. Vide *Kirch. Phonurg.*

Ol. Magnus ſpeaking of the vaſt high mountains of a northern province, called *Angermannia*, ſaith, *Ubi baſes eorum in profundiſſimo gurgite ſtantes, caſu aliquo, vel propoſito nautæ acceſſerint, tantum horrorem ex altâ fluctnum colliſione percipiunt, ut niſi præcipiti remigio, aut valido vento evaſerint, ſolo pavore ferè exanimes fiant, multoque dierum curriculo, ob capitis turbationem, priſtinæ mentis, & ſanitatis compotes vix evadant. Habent baſes illorum montium in fluctuum ingreſſu & regreſſu tortuoſas rimas, ſive ſciſſuras, ſatis ſtupendo naturæ opificio fabricatas, in quibus longâ voragine formidabilis ille ſonitus quaſi ſubterraneum tonitru generatur.*— "If any ſailors ſhould chance to approach the baſes of thoſe mountains which ſtand in the midſt of a deep gulph, they are ſtruck with ſuch horror from the prodigious daſhing of the waves, that unleſs they eſcape by quick rowing, or by the wind favouring them, they become ſtupified with fright, and ſcarcely recover their ſenſes or former health. The baſes of thoſe mountains have many winding cavities, ſtupendouſly formed, from whoſe deep receſſes iſſues a dreadful ſound like ſubterraneous thunder."—*Ol. Magn.* l. 2. c. 4. See alſo *chap.* 12.

(*bb*) That the air is the ſubject, or *medium* of ſound, is manifeſt from the experiments in rarefied and condenſed air. In an unexhauſted receiver, a ſmall bell may be heard at the diſtance of ſome paces; but when exhauſted, it can ſcarce be

 heard

ætherial part thereof, or soniferous particles of bodies, as some fancy, or whatever else the philosophers

heard at the nearest distance: and if the air be compressed, the sound will be louder, proportionably to the compression or quantity of air crouded in, as I have often tried myself, and may be seen in Mr. *Hawksbee*'s curious experiments, *p.* 97. Also his experiments in *Phil. Trans.* No. 321.

Neither doth this succeed only in forced rarefactions and condensations of the air, but in such also as are natural; as is evident from *David Frœdlichius* in *Varenius*, upon the highest eminencies of *Carpathus*, near *Kesmarckt* in *Hungary*. The story of *Frœdlichius* is this, *Ego mense Junii* 1615. *tum adolescens, sublimitatem horum montium, cum duobus comitibus scholaribus, experiri volens, ubi, cùm in primæ rupis vertice, magno labore, me summum terminum assecutum esse putarem, demum sese obtulit alia multo altior cautes, ubi pervasta eaque vacillantia saxa (quorum unum, si loco à viatore dimovetur—aliquot centena—rapit, & quidem tanto cum fragore, ut illi metuendum sit nè totus mons corruat, eumque obruat) enixus essem, iterum alia sublimior prodiit,* &c. *donec summo vitæ periculo ad supremum cacumen penetraverim. Ex declivioribus montibus cùm in subjectas valles,—nil nisi obscuram noctem, aut cæruleum quid, instar profundi aëris, quod vulgò nudum cælum appellatur, observare potui mihique videbar, si de monte caderem, non in terram, sed rectè in cælum me prolapsurum. Nimia enim declivitate, species visibiles extenuatæ & hebetatæ fuerunt. Cum verò altiorem montem peterem, quasi intra nebulas densissimas hærebam—Et cum non procul à summo vertice essem, de sublimi quiescens prospexi & animadverti iis in locis, ubi mihi antea videbar intra nebulas hæsisse, compactas atque albas sese movere nubes, supra quas, per aliquot milliaria, & ultra terminos Sepusi commodus mihi prospectus patuit. Alias tamen etiam nubes altiores, alias item humiliores, necnon quasdam æqualiter à terrâ distantes vidi. Atque hinc tria intellexi,* 1. *Me tum transivisse principium mediæ aeris regionis.* 2. *Distantiam nubium à terra, non esse æqualem.* 3. *Distantiam nubium—non* 72 *mill. Ger. ut quidam—sed tantum dimidiatum mill. Ger. In summum montis verticem cùm pervenissem, adeò tranquillum & subtilem aërem ibi offendi,* ut

phers may think it. For who but an intelligent being, what lefs than an omnipotent and infinitely wife God

ut nè pili quidem motum fentirem, cùm tamen in depreffioribus ventum vehementem expertus fim: unde collegi fummum cacumen iftius montis Carpathici ad mill. Ger. à radicibus fuis imis exfurgere, & ad fupremum ufque aëris regionem, ad quam venti non afcendant, pertingere. Explofi in eà fummitate fclopetum: quod non majorem fonitum primò præ fe tulit, quàm fi ligillum vel bacillum confregiffem; poft intervallum autem temporis murmur prolixum invaluit, inferiorefque montis partes, convalles & fylvas opplevit. Defcendendo per nives annofas intra convalles, cùm iterum fclopetum exonerarem, major & horribilior fragor, quàm ex tormento capaciffimo inde exoriebatur: hinc verebar nè totus mons concuffus mecum corrueret; duravitque hic fonus per femiquadrantem horæ ufque dum abftrufiffimas cavernas penetrâffet, ad quas aër undique multiplicatus refiliit.— In his celfis montibus, plerumque ningit grandinatve mediâ æftate, quoties nempe in fubjectâ & vicinâ planitie pluit, uti hoc ipfum expertus fum. Nives diverforum annorum ex colore & cortice duriore dignofci poffunt.—" When I was a youth, having in June 1615 a defire to explore the height of thofe mountains, I afcended together with two of my fchool-fellows; and when, with much labour, I had got to the top of the firft rock, and believed myfelf at the fummit of all, there appeared another much higher, and covered with large and loofe ftones, any one of which being moved, would carry fome hundreds along with it, with fuch a noife as if the whole mountain were tumbling. Having gained this afcent, another and another ftill appeared; till at length, with infinite labour and imminent danger of my life, I reached the top of all. When from thefe afpiring cliffs I looked down into the valleys below, the appearance was like that of dark night, or like that deep blue expanfe of air which we call the fky: and I thought that if I fhould fall, I fhould drop into the fky, and not down to the earth: for the vifible objects from the prodigious height were totally blended and confufed in one undiftinguifhed mafs. But having afcended yet a higher mountain I came into thick clouds, and there fitting down at a little diftance from the

God could contrive, and make ſuch a fine body, ſuch a medium, ſo ſuſceptible of every impreſſion, that

ſummit, I looked around me and obſerved the denſe white clouds in motion below, and over theſe I had a clear and moſt extenſive proſpect for many miles beyond the boundaries of the country of Sepuſum. I ſaw likewiſe ſome clouds higher, ſome lower, and ſome in the middle ſpace between me and the earth. And hence I drew three concluſions. 1. That I had paſſed the beginning of the middle region of the air. 2. That the diſtance of the clouds from the earth is not always the ſame. 3. That their diſtance is not, as ſome have aſſerted, about 72 German miles, but only half a German mile from the earth. When I had come to the top of the mountain, I found the air ſo tranquil and ſo ſubtile, as not to give motion to a hair, although in the lower regions I had found the wind very high; whence I concluded that the higheſt ſummit of mount Carpathus riſes about a German mile from its baſe into the upper region of the air, where the winds never reach. I fired a piſtol upon the top, which at firſt made no greater noiſe than if I had broken a ſmall ſtick; but after a while there was a long continued murmur from below, riſing from the valleys and the woods which covered the lower part of the mountain. On coming down through the old beds of ſnow into the valleys, I fired another piſtol, and there enſued a great and horrible noiſe, as from the largeſt cannon, ſo that I was afraid the whole mountain would have fallen upon me: and this ſound laſted for half a quarter of an hour, till it had penetrated into the innermoſt caverns, whence it was echoed back in every direction. On theſe high mountains it generally hails or ſnows at midſummer, whenever there is rain in the lower regions, as I found by experience. The ſnows of different years may be diſtinguiſhed by their colour and more indurated ſurface."—*Varen. Georg. Gen.* l. i. c. 19. prop. ult.

The ſtory being diverting, and containing divers things remarkable, I have choſen to note the whole of it (although ſomewhat long) rather than ſingle out the paſſages only which relate

to

that the ſenſe of hearing hath occaſion for, to empower all animals to expreſs their ſenſe and meaning to others; to make known their fears, their wants, their pains and ſorrows in melancholic tones; their joys and pleaſures in more harmonious notes; to ſend their minds at great diſtances (*cc*), in

to the diminiſhing the ſound of his piſtol, by the rarity of the air at that great aſcent into the atmoſphere; and the magnifying the ſound by the polyphoniſms or repercuſſions of the rocks, caverns, and other phonocamptick objects below in the mount.

But 'tis not the air alone that is capable of the impreſſions of ſound, but the water alſo, as is manifeſt by ſtriking a bell under water, the ſound of which may plainly enough be heard, but it is much duller, and not ſo loud; and it is alſo a fourth deeper, by the ear of ſome great judges in muſical notes, who gave me their judgments in the matter. But *Merſenne* ſaith, a ſound made under water, is of the ſame tone or note, if heard under water; as are alſo ſounds made in the air, when heard under water. Vide *Merſen. Hydraul.*

Having mentioned the hearing of ſounds under water, there is another curioſity worth mentioning, that alſo farther proves water to be ſuſceptible of the impreſſions of ſound, viz. *Divers* at the bottom of the ſea can hear the noiſes made above, only confuſedly. But, on the contrary, thoſe above cannot hear the divers below. Of which an experiment was made, that had like to have been fatal: one of the divers blew an horn in his diving-bell, at the bottom of the ſea; the ſound whereof (in that compreſſed air) was ſo very loud and irkſome, that it ſtunned the diver, and made him ſo giddy, that he had like to have dropt out of his bell, and to have been drowned. Vide *Sturmii Colleg. Cur.* vol. ii. *Tentam.* 1.

(*cc*) As to the diſtance to which ſound may be ſent, having ſome doubt, whether there was any difference between the northern

in a short time (*dd*), in loud boations; or to express their thoughts near at hand with a gentle voice,

thern and southern parts, by the favour of my learned and illustrious friend sir *Henry Newton*, her late majesty's envoy at *Florence*, I procured some experiments to be made for me in *Italy*. His most serene highness the *Great Duke* was pleased to order great guns to be fired for this purpose at *Florence*, and persons were appointed on purpose to observe them at *Leghorn*, which they compute is no less than 55 miles in a strait line. But notwithstanding the country between being somewhat hilly and woody, and the wind also was not favouring, only very calm and still, yet the sound was plainly enough heard. And they tell me, that the *Leghorn* guns are often heard 66 miles off, at *Porto Ferraro*; that when the *French* bombarded *Genoa*, they heard it near *Leghorn*, 90 miles distant; and in the *Messina insurrection*, the guns were heard from thence as far as *Augusta* and *Syracuse*, about 100 *Italian* miles. These distances being so considerable, give me reason to suspect, that sounds fly as far, or nearly as far, in the southern, as in the northern parts of the world, notwithstanding we have a few instances of sounds reaching farther distances. As Dr. *Hearn* tells us of guns fired at *Stockholm* in 1685, that were heard 180 *English* miles. And in the *Dutch* war, 1672, the guns were heard above 200 miles. Vide *Phil. Trans.* No. 113. Also there is this farther reason of suspicion, that the *mercury* in the *barometer* riseth higher without than within the tropics, and the more northerly, still the higher, which may increase the strength of sounds, by *note* (*bb*).

(*dd*) As to the velocity of sounds, by reason the most celebrated authors differ about it, I made divers nice experiments myself, with good instruments; by which I found, 1. That there is some, although a small difference in the velocity of sounds, with or against the wind: which also is, 2. Augmented or diminished by the strength or weakness of the wind. But that nothing else doth accelerate or retard it, not the differences of

voice, or in ſecret whiſpers! And, to ſay no more, who leſs than the ſame moſt wiſe and indulgent Creator, could form ſuch an œconomy, as that of melody and muſic is; that the *medium* ſhould (as I ſaid) ſo readily receive every impreſſion of ſound, and convey the melodious vibration of every muſical ſtring, the harmonious pulſes of every animal voice, and of every muſical pipe; and the ear be as well adapted, and ready to receive all theſe impreſſions, as the *medium* to convey them: and laſtly, that by means of the curious lodgment, and inoſculations of the *auditory nerves* before-mentioned, the orgaſms of the ſpirits ſhould be allayed, and perturbations of the mind in a great meaſure quieted and ſtilled (*ee*): or to expreſs it in the words of the laſt-cited

of day or night, heat or cold, ſummer or winter, cloudy or clear, barometer high or low, &c. 3. That all kinds of ſounds have the ſame motion, whether they be loud or languid, of bells, guns, great or ſmall, or any other ſonorous body. 4. That they fly equal ſpaces in equal times. Fifthly and laſtly, That the mean of their flight is at the rate of a mile in nine half ſeconds and a quarter, or 1142 feet in one ſecond of time. Vide *Phil. Tranſ. Ibid.*

(*ee*) *Timotheus* a muſician could excite *Alexander the Great* to arms with the *Phrygian* ſound, and allay his fury with another tone, and excite him to merriment. So *Ericus* king of *Denmark*, by a certain muſician, could be driven to ſuch a fury, as to kill ſome of his beſt and moſt truſty ſervants. More of this power of muſic over the affections may be ſeen in *Ath. Kirch. Phonurg.* l. 2. ſect. 1. Alſo in *Iſ. Voſſius de Poëmatum cantu, & Rythmi viribus.*

And

cited famous author (*ff*), " That muſic ſhould " not only affect the fancy with delight, but alſo " give

And not only upon the affections, but alſo on the parts of the body, muſic is able to exert its force, as appears from the *Gaſcoign* knight, *Cui phormingis ſono audito veſica ſtatim ad urinam reddendam vellicabatur*—" Who at the ſound of a bagpipe felt an irritation of the bladder provoking him to make water."—Such another we have in No. 1. *Ephem. Nat. Curioſ. Obſerv.* 134. Alſo *Morhoff de Scyph. vitr. per cert. human. vocis ſonum fracto:* where there is not only the account of the *Dutchman* at *Amſterdam*, one *Nich. Peter*, that brake Roman glaſſes with the ſound of his voice; but alſo divers other inſtances of the powers and effects of ſound. But to the ſtory of the *Gaſcoign* knight, Mr. *Boyle*, from *Scaliger*, adds a pleaſant paſſage, That one he had diſobliged, to be even with him, cauſed at a feaſt, a bagpipe to be played, when he was hemmed in with the company; which made the knight be-piſs himſelf, to the great diverſion of the company, as well as confuſion of himſelf. *Boyle's Eſſay of the Effect of Lang. Motion.* In the ſame book are other matters that may be noted here. One whoſe arm was cut off, was exceedingly tormented with the diſcharge of the great guns at ſea, although he was at a great diſtance on land. And a great ſhip-commander obſerved his wounded men, with broken limbs, ſuffered in like manner at the enemies diſcharges. An ingenious domeſtic of his own would have his gums bleed at the tearing of brown paper. And a gentleman of Mr. *Boyle*'s acquaintance confeſſed to him, that he was inclined to the *knight of Gaſcoign's diſtemper*, upon hearing the noiſe of a tap running. The dancing to certain tunes, of perſons bit with the *tarantula*, he was aſſured of by an ingenious acquaintance at *Tarentum*, who ſaw ſeveral, amongſt the reſt a phyſician, affected with that diſtemper. And many other accounts of this kind, ſeemingly credible, are related in *Morhoff*, *Kircher*, and many others; although Dr. *Cornelio* queſtions the matters of fact relating to the

" give relief to the grief and ſadneſs of the heart;
" yea, appeaſe all thoſe turbulent paſſions, which
" are

the cure of the *tarantula* bite, in *Phil. Tranſ.* No. 83. Mr. *Boyle* alſo ſaith, a ſober muſician told him, he could make a certain woman weep, by playing one tune, which others would be little affected at. And he ſaith, that he himſelf had a kind of ſhivering at the repeating two verſes in *Lucan*. And I add, that I very well know one to have a ſort of chill about his *præcordia* and head, upon reading or hearing the 53d chapter of *Iſaiah*; as alſo *David*'s lamentations for *Saul* and *Jonathan*, 1 *Sam*. i.

Neither are our own minds and bodies only affected with ſounds, but inanimate bodies are ſo alſo. Of which many ſtories may be met with in *Kircher*, particularly a large ſtone that would tremble at the ſound of one particular organ-pipe; in *Morhoff* alſo, who among many other relations hath this, *Memini cum ipſi* [*clariſ. Williſio*] *de experimento vitri per vocem fracti narrarem, ex eo audiviſſe, quod in ædibus muſicis ſibi vicinis aliquoties collapſum pavimentum fuerit*; *quod ipſe ſonis continuis adſcribere non dubitavit.*—" I remember when I was telling him (Dr. Willis) of the experiment of breaking a glaſs by a man's voice, he informed me that he obſerved in a muſic-hall in his neighbourhood, the pavement fallen in, which he attributed to the repeated force of the ſounds."—*Morhoff*. cap. 12. *Merſenne* alſo, among many relations in his *Harmon.* and other books, tells a far more probable ſtory, of a particular part of a pavement, that would ſhake, as if the earth would open, when the organs played, than what he relates about *antipathy*, in his *Quæſt. Comment. in Geneſ.* viz. That the ſound of a drum made of a wolf's ſkin, will break another made of ſheep's ſkin: that hens will fly at the ſound of an harp ſtrung with fox-gut ſtrings, and more to the ſame purpoſe. Mr. *Boyle* alſo, in his laſt cited book, tells us, ſeats will tremble at the ſound of organs; and that he hath felt his hat to do ſo too under his hand, at certain notes both of organs, and in

" are excited in the breaſt by an immoderate fer-
" ment, and fluctuation of the blood."

And now, who can reflect upon all this curious apparatus of the *ſenſe of hearing*, and not give the great Creator his due praiſe! Who can ſurvey all this admirable work, and not as readily own it to be the work of an omnipotent, and infinitely wiſe

in diſcourſe; that he tried an arch that would anſwer to C fa-ut, and had done ſo an 100 years; and that an experienced builder told him any well-built vault will anſwer ſome determinate note. And at *Eaſtbury-houſe* near *Barking*, I myſelf diſcovered the porch, (having firm brick-walls,) not only to ſound when ſtruck on the bottom, but alſo to give almoſt as loud a ſound, when I ſounded the ſame note with my voice *.

(*ff*) *Willis*, ubi ſupra.

* Every ſubſtance whatever, whoſe parts are ſo connected as to be capable of an uniform vibration, may have that vibration produced in it by the ſounding of a certain muſical note or tone with which it is in uniſon. Even liquids, when ſo ſuſpended as to be capable of vibration, (as for example water in a glaſs,) are obſerved, not only to vibrate when a particular note is ſtruck or ſounded, but actually ſound themſelves in concord. That water ſuſpended in a glaſs becomes actually itſelf a ſonorous body, is proved by the mode of tuning a ſet of muſical glaſſes, which become the deeper in tone, the more water is poured into them; for if it was only the empty part of the glaſs that ſounded, the ſound would be the more acute, the more water was poured in. But as the contrary holds true, it is thence evident that the water and glaſs together form one uniform ſonerous ſubſtance, of which the greater the quantity or volume, the deeper is its muſical tone. EDITOR.

wiſe and good GOD (gg), as the moſt artful melodies we hear, are the voice or performances of a living creature!

(gg) *Ille Deus eſt—qui non calamo tantùm cantare, & agreſte atque inconditum carmen ad aliquam tantùm oblectationem modulari docuit, ſed tot artes, tot vocum varietates, tot ſonos, alios ſpiritu noſtro, alios externo cantu edituros commentus eſt.*—" He indeed is God—It is he who not only has taught the uſe of inſtruments and the ſkill of muſical ſounds, but has framed the utmoſt variety of voices and of ſounds; the author of every art."—*Senec. de Benef.* l. 4. c. 6.

CHAP. IV.

Of the Senſe of Smelling.

THIS ſenſe I ſhall diſpatch in leſs compaſs than the two laſt, becauſe its apparatus (although ſufficiently grand and admirable, yet) is not ſo multiplicious as of the eye and ear; it being ſufficient in this ſenſe, that the odoriferous effluvia of bodies (*a*) can have an eaſy, free paſſage to the olfactory nerves, without the formalities of refractions, and other preparations neceſſary to the perfection of the two former ſenſes. Accordingly, the all-wiſe Creator hath made ſufficient proviſion for the reception of ſmells, by the apertures of the noſtrils (*b*); made not of fleſh, or bone, but cartilaginous

(*a*) A piece of *ambergreaſe* ſuſpended in a pair of ſcales, that would turn with a very ſmall part of a grain, loſt nothing of its weight in three days and half; neither did *aſſafœtida* in five days and half: but an ounce of *nutmegs* loſt five grains and half in ſix days; and *cloves* ſeven grains and four-fifths.—*Boyle's Subtil. of Efflux.* c. 5.

(*b*) *Nares, eò quòd omnis odor ad ſuperiora fertur, rectè ſurſum ſunt: Et quòd cibi & potionis judicium magnum earum eſt, non ſine cauſâ vicinitatem oris ſecutæ ſunt.*—"The noſtrils are rightly placed upwards, as all ſmells aſcend: and they are placed in the neighbourhood of the mouth, becauſe they are of infinite uſe in the diſcrimination of meats and drinks."—*Cic. de Nat. Deor.* l. 2. c. 56.

laginous, the better to be kept open, and withal, to be dilated or contracted, as there is occasion: for which service the nose hath several proper and curious muscles (*c*).

And forasmuch as it is by breathing (*d*), that the odorant particles are drawn in, and conveyed to the sensory; therefore there is a very wise provision made in the *laminæ*, with which the upper part of the nose is barricaded, which serve to two excellent uses: partly, to fence out any noxious substances from entering the breathing passages in our sleep, or when we cannot be aware (*e*); and partly, to receive the divarications of the *olfactory nerves*, which are here thick spread, and which do by these means meet the smells entring with the breath, and striking upon them.

(*c*) Had not the contriver of animal bodies been minded that his work should have all the signatures of accuracy, this sense might have been performed with a bare aperture of the nose; but that nothing might go imperfect out of his hand, he hath made a part of the nose easily moveable, and given a set of muscles to lift up, and open and shut the nostrils; and so adjust it to every occasion of this sense.

(*d*) *Odorem non aliud, quàm infectum aëra, intelligi posse.*—"We understand that odour proceeds from nothing else than tainted air."—*Plin. Nat. Hist.* l. 9. c. 7.

(*e*) For a further guard against the ingress of noxious things, the *vibrissi*, or hairs placed at the entrance of the nostrils serve, which, in some measure stop the entrance of things improper, or, however, give warning of them; but at the same time allow an easy passage to the breath and odours.

And accordingly, the more accurate this ſenſe is in any animal, the longer we may obſerve thoſe *laminæ* are; and more of them in number folded up, and crowded together, to contain the more nervous filaments, and to detain and fetter the odoriferous particles in their windings and turnings.

And an admirable proviſion this is, which the great Creator hath made for the good of brute creatures (*f*); the chief acts of many of whoſe lives are performed by the miniſtry of this ſenſe.

(*f*) *Multo præclarius emicat* [*olfactus*] *in brutis animalibus, quàm in homine: iſta namque hoc ſolo indice, herbarum, aliorumque corporum priùs ignotorum virtutes certiſſimè dignoſcunt, quin & victum ſuum abſentem, vel in abſtruſo poſitum, odoratu venantur, ac facillimè inveſtigant. Quòd autem minùs ſagaces ſunt hominum nares, illud non facultatis hujus abuſui (prout nonnulli volunt) aſcribi debet, verùm in causâ eſt ipſius organi defectus: hoc enim circa victûs humani criteria (ubi ratio, & intellectus adſunt) non ita accuratum requiritur: propterea enim inferiores potentiæ in homine, à naturâ minùs perfectæ exiſtunt, ut ſuperiorum cultui & exercitio relinqueretur locus.*—"The ſmell is much more excellent in brute animals than in man; for by it alone they diſtinguiſh with certainty the qualities of herbs and other ſubſtances with which they were before unacquainted; and hunt out and diſcover their food wherever it is concealed. That man is not endowed with the ſame ſagacity of the noſe, is not to be aſcribed, as ſome would have it, to the abuſe of that faculty, but to an inherent defect of the organ: for man having reaſon and underſtanding to direct him, has no occaſion for that acuteneſs of ſmell to diſtinguiſh his food. On this account too the inferior faculties are leſs perfect in man, that there may be more room for the exerciſe of his ſuperior endowments."—*Willis de Anim. Brut.* c. 13.

In

In infects, and many other creatures, it is of great ufe in the propagation of their kind; as particularly in helping them to fafe and convenient places for the incubation of their eggs, and breeding up their young. Others are by the accuracy of this fenfe, of ufe to mankind, which would be otherwife of little or no ufe (*g*). And moft of the irrational animals, birds, beafts, and creeping things, do, by their fmell, find out their food; fome at great diftances, and fome at hand. With what fagacity do fome difcover their food in the midft of mud and dirt (*h*)? With what curiofity do the herbaceous kind pick and chufe fuch plants as afford them wholefome food, or fometimes fuch as are medicinal (*i*), and refufe fuch as would hurt and deftroy them? And all by the help principally, if not only, of the fmell, affifted by its near ally the tafte. Of which I fhall in the next place fpeak very briefly.

(*g*) Thus the chief ufe of hounds is to hunt; and other dogs, to be a watch and guard to our houfes by night. For which fervices (particularly in hounds) their *olfactory nerves* are not only remarkably large, (like as they are in other brutes,) but their branches and filaments are, in the *laminæ* of the noftrils, both more and larger than I have feen in any other creature whatfoever. Alfo there are more convulfions of the *laminæ* than I ever remember to have found in any other animal.

The fagacity of hounds is prodigious; of which fee an inftance in *book* iv. *chap.* 11. *note* (*hhh*).

(*h*) See *book* vii. *chap.* 2. *note* (*e*).

(*i*) *Vide Plin. Hift. Nat.* l. 8. c. 27. *Quæ animalia quas herbas oftenderunt.*

CHAP. V.

Of the Taste (*a*).

IN this, as in the laſt ſenſe, we have an *apparatus* abundantly ſufficient to the ſenſe; nerves curiouſly divaricated about the tongue (*b*), and mouth,

(*a*) Τὰ δὲ εἴδη τῶν χυλῶν, &c. *Saporum genera—dulcis, pinguis, auſterus, acerbus, acris, ſalſus, amarus, acidus.*—"The different kinds of taſtes are the ſweet, the fat, the auſtere, the harſh, the acrid, the ſalt, the bitter, the ſour."—*Theophr. de Cauſ. Plant.* l. 6. c. 1. What may be the cauſe of the difference of taſtes, he ſaith is hard to aſſign, πότερον γὰρ τοῖς πάθεσι, &c. *Utrum affectionibus ſenſuum—an figuris, quibus ſinguli conſtant, ut Democritus cenſet.* id. ib. Δημόκριτος δὲ, &c. *Democritus—dulcem eſſe ſaporem qui rotundus; acerbum qui figurâ magnâ; aſperum qui multis angulis,* &c.—"Whether theſe differences are to be attributed to the affections of the ſenſes, or as Democritus thinks, to the figures of which the ſubſtances are compoſed. It is his opinion, that where the figures are round, the taſte is ſweet, where they are cornered, the taſte is ſharp, &c."—*Id. Ib.* &c. But of the diverſities and cauſes of taſtes, ſee Dr. *Grew, Lect.* 6. and Dr. *Willis de Anim. Brut.* c. 12.

(*b*) *Intellectus ſaporum eſt cæteris in primâ linguâ: homini, & in palato.*—"The perception of taſtes is ſituated in the tip of the tongue in moſt animals: but in man, it is likewiſe in the palate."—*Plin.* l. 11. c. 37.

The opinions of anatomiſts concerning the organ of *taſte* are various. *Bauhin, T. Bartholin, Bartholette, Veſlinge, Deuſinge,* &c. place it in the laxer, fleſhy parts of the tongue: our famous *Wharton*, in the gland at the root of the tongue: *Laurentius* in the thin tunic covering the tongue; but the learned *Malpighi* with great probability concludes, becauſe the outward cover of the tongue is perforated, under which lie papillary parts, (of which Mr. *Cowper* hath very good cuts

mouth, to receive the impreſſions of every guſto; and theſe nerves guarded with a firm and proper tegument to defend them from harms; but withal ſo perforated in the papillary eminences, as to give a free admiſſion to taſtes.

But I ſhall ſay no more of this ſenſe; only a word or two of its conſent with the ſmell, and

cuts in his *Anat. Tab.* 13.) that in theſe the taſte lieth. *Malpighi*'s words are, *Quare cùm dictis meatibus inſignibus occurrant papillaria corpora, probabilius eſt in his ultimo, ex ſubintranti ſapido humore titillationem, & mordicationem quandam fieri, quæ guſtum efficiat.*—"As we find under theſe pores certain papillary parts, it is probable that in theſe lies the ſenſe of taſting, which is produced by the ſapid humour entering, and ſlightly ſtimulating theſe parts."—*Malpig. Op. tom.* 2. *de Linguâ*, p. 18.

Præcipuum ac ferè ſolum guſtatûs organon eſt lingua; cui aliquatenus ſubobſcurè tamen palatum, & ſuperior gulæ pars conſentiunt: in omnibus verò fibræ nervoſæ immediata ſenſionis inſtrumenta ſunt. Quare obſervare eſt, linguam præ aliâ quâvis parte inſigniter fibroſam eſſe, etiam texturâ valdè poroſâ conſtare, in eum nempe finem, ut particulæ rei ſapidæ copioſiùs ac penitiùs intra ſenſorii meatus admittantur.—Nervi autem qui fibris linguæ denſiſſimè intertextis famulantur, ac ſaporum impreſſiones τῷ πρώτῳ αἰσθητηρίῳ *communicant, ſunt.—Nervi è paribus tum quinto, tum nono; & ubiq; cum denſâ propaginum ſerie per totam ejus compagem diſtributi.*—"The principal and almoſt the ſole organ of taſte is the tongue, although the palate and the upper part of the throat are in ſome degree ſubſervient. But in all theſe the nervous fibres are the immediate inſtrument of ſenſe. On that account we obſerve, that the tongue is much more fibrous than any other part, and is of a very porous contexture; that thus the ſapid particles of the food may be more intimately communicated to the paſſages of the *ſenſorium*. The nerves which communicate to the fibres of the tongue are thoſe of the fifth and ninth pair; and theſe by various ramifications are diſtributed through all its contexture."—*Willis, ibid.* (See Plate C, in book v. c. 8.)

the ſituation of them both: their ſituation is in the moſt convenient place imaginable, for the diſcharge of their offices; at the firſt entrance (*c*), in the way to the grand receptacle of our food and nouriſhment; to ſurvey what is to be admitted therein; to judge between what is wholeſome, and fit for nouriſhment, and what is unſavoury and pernicious. And for this end, the all-wiſe Creator ſeems to have eſtabliſhed a great conſent between the eye, the noſe, and tongue, by ordering the branches of the ſame nerves (*d*), to each of thoſe three parts; as alſo indeed, to divers

(*c*) *Guſtatus, qui ſentire eorum quibus veſcimur genera debet, habitat in eâ parte oris, quâ eſculentis & potulentis iter naturæ patefecit.*—"The ſenſe of taſting, as it ſerves for the diſcrimination of our foods, is placed in that part of the mouth where the food firſt enters."—*Cic. de Nat. Deor.* l. 2. c. 56. *Vide quoq; ſupra*, note (*b*), chap. 4.

(*d*) *Multæ hujus* [quinti Paris] *nervi propagines maſticationis operi deſtinantur; ideoque quoniam alimenta ingerenda non modò guſtûs, aſt etiam olfactûs & visûs examen ſubire debent, ab eodem nervo, cujus rami ad palatum & fauces miſſi, manducationis negotium peragunt, propagines aliæ, velut exploratrices, ad nares & oculos feruntur, nempe ut iſthæc aliorum ſenſuum organa, etiam ad objecta guſtûs melius dignoſcenda probationum auxiliis quibuſdam inſtruantur.*—"Several of the branches of the fifth pair of nerves are ſubſervient to maſtication: and as the food ought not only to undergo the examination of the taſte, but likewiſe of the ſmell and of the ſight, ſo from the ſame nerve, whoſe branches paſſing to the palate and *fauces*, ſerve for manducation; there are other branches which are ſent to the noſtrils, and to the eyes, in order that theſe organs may likewiſe contribute their aid towards diſtinguiſhing the proper objects of taſte."—*Willis Nerv. Deſcrip. & Uſus.* c. 22. (See Plate C, in book v. c. 8.)

other

other parts of the body, which I may have occasion to mention in a more proper place (*e*). By which means, there is all the guard that can be, against pernicious food; forasmuch, as before it is taken into the stomach, it is to undergo the trial of three of the senses; the scrutiny of the eye, the strict surveyor of its outward appearance; and the probation of the smell and taste, the two severest judges of its natural constitution and composition.

(*e*) See *book* v. *chap.* 8.

CHAP. VI.

Of the Senſe of Feeling (*a*).

HAVING ſpent ſo much time upon the other ſenſes, and therein given ſuch ample proofs of the infinite Creator's wiſdom; I ſhall but briefly take

(*a*) *Malpighi* is of this opinion, that as *taſte* is performed by the *papillæ* in the tongue, ſo is *feeling* by ſuch like *papillæ* under the ſkin. From ſeveral diſſections, and other obſervations, he thus concludes, *Ex his & ſimilibus videbatur animus abundè certior redditus, earundem papillarum pyramidalium copiam, quas aliàs in linguâ deſcripſi, in locis præcipuè acquiſitiori tactui dicatis reperiri, eodem progigni nervoſo & cuticulari corpore, ſimulque circumvolvi reticulari involucro, & extiman cuticulam, veluti ultimum terminum attingere.—Microſcopio quilibet in manûs dorſo pro ſudore orificia quædam miro ordine diſperſa intueri poteſt, circa quæ frequentia quædam capitula aſſurgunt; hæc verò ſunt papillarum fines, dum à cute aſſurgentes interpoſitum ſuperant rete, ſimulque extimam cuticulam. Hæc repetitis ſectionibus deprehendi; ex quibus non improbabiliter deducam, ſicuti ex elatioribus—papillis—in linguâ, guſtûs organon elicitur,—ita ex copiosâ harum papillarum congerie—in organis, ubi maximè animalia tactûs motione afficiuntur,—adæquatum tactûs organum ſufficientèr haberi.*—" From theſe and ſimilar obſervations we are abundantly certain, that the ſame pyramidal *papillæ*, which we have deſcribed in the moſt ſenſible part of the tongue, are likewiſe found in the nervous and cuticular ſubſtance, where they are covered with a reticular or netted ſubſtance, and have their termination in the outward cuticle.—Any perſon may, with the help of a microſcope, perceive upon the back of the hands certain orifices for giving vent to the ſweat, diſtributed in wonderful order, around which there ariſe many ſmall heads or points. Theſe are the extremities

take notice of two things relating to this laſt ſenſe.

One is its organ, the nerves. For as all ſenſation is performed by the nerves (*b*), and indeed the other ſenſes (performed by nerves) are a kind of feeling; ſo is this ſenſe of *feeling* performed by nerves likewiſe, ſpread in the moſt incomparable, curious manner throughout the whole body. But to deſcribe their origin in the brain, and ſpinal-marrow, their ramifications to all the parts; their inoſculations with one another; and other matters;

extremities of the *papillæ* riſing from the *cutis* above the reticular ſubſtance, and the outward cuticle. Theſe I have found upon repeated diſſections; whence I conclude with ſome probability, that as the taſte is produced by the papillæ in the tongue, ſo the ſenſe of feeling ariſes from the ſame *papillæ* in thoſe organs where the touch is moſt acute and ſenſible."—*Malpig. de extern. Tact. Org.* p. 26. Conſul. quoq; ejuſd. Vit. *p.* 28.

Theſe obſervations of *Malpighi*, our late curious and diligent Mr. *Cowper* hath confirmed, and given us very elegant cuts both of the ſkin, and the *papillæ*, and the nerves, glands, *&c.* under it, from microſcopical obſervations. *Vide Cowper's Anat. introd.* and *tab.* 4.

(*b*) Although the eye be the uſual judge of colours, yet ſome have been able to diſtinguiſh them by their feeling. *Quidam fuit qui venit ad M. Duc.* Hetruriæ *aulam qui colores per tactum cognoſcebat. Pro experimento velum ſericum, uniformiter textum, & pluribus coloribus tinctum, offerebatur, & veracitèr de colore in ſingulis partibus judicabat.*—" A certain perſon came to the court of the Duke of Tuſcany who could diſtinguiſh colours by the touch. By way of experiment, a ſilk veil was laid before him, which was uniformly wove throughout, but dyed with ſeveral colours, and he diſtinguiſhed the colours in the different parts with the greateſt accuracy."—*Grimald. de Lum. & Col.* prop. 43. ſect. 59.

ters; whereby not only the ſenſe of *feeling* is performed, but alſo animal motion, and admirable conſent and harmony of all the parts of the body is effected: (to deſcribe, I ſay, theſe things,) would take up too much time, and I have already, and ſhall, as I go along, give ſome hints thereof. (See *poſtea*, book v. c. 8.; and Plate C, with its explanation.)

The other thing I ſhall take notice of, is, the diſperſion of this ſenſe throughout the body, both without and within. The other ſenſes, I have obſerved, are ſeated in the very beſt place for the relief and comfort, the guard and benefit of the animal. And foraſmuch as it is neceſſary to the being, and well-being of the body, that every part ſhould be ſenſible of things ſafe, or things prejudicial to itſelf; therefore, it is an admirable contrivance of the great Creator, to diſperſe this ſenſe of *feeling* throughout every part (*c*); to diſ-

(*c*) *Tactus autem toto corpore æquabilitèr fuſus eſt, ut omnes ictus, omneſque nimios & frigoris, & caloris appulſus ſentire poſſimus.*—" The ſenſe of feeling is diffuſed over all the body, that we may be ſenſible of every thing that ſtrikes againſt it, and likewiſe of the extremes of heat and of cold."—*Cic.* ubi ſupra.

Tactus ſenſus omnibus eſt, etiam quibus nullus alius; nam & oſtreis, & terreſtribus vermibus quoque. Exiſtimaverim omnibus ſenſum & guſtatûs eſſe. Cur enim alios alia ſapores appetunt? in quo vel præcipua Naturæ architectio.—" All animals have the ſenſe of feeling, even thoſe which ſeem to have no other ſenſe, as for example, oyſters and earth worms. I ſhould imagine, however, that all have likewiſe the ſenſe of taſte; for how, otherwiſe, ſhould different animals reliſh different taſtes? The mechaniſm of Nature is admirable in this."—*Plin. Nat. Hiſt.* l. 10. c. 71.

tinguiſh

tinguiſh between pleaſure and pain; things ſalutary, and things hurtful to the body.

Thus in the five ſenſes of animals, we have an œconomy worthy of the Creator, and manifeſtly demonſtrating his power, wiſdom, and indulgence. For whether we conſider the mechaniſm of the organs, or the great uſe and convenience of each ſenſe, we find it noble and grand, curious and artificial; and every way worthy of its infinite Maker, and beyond the wit and power of any thing but a God: and therefore we muſt even deny our ſenſes, by denying them to be God's handywork.

And now from thoſe chief machines of animal performances and enjoyments, the five ſenſes; let us paſs to another thing in common to all the ſenſitive creatures, which is Reſpiration.

CHAP. VII.

Of Reſpiration.

OF all the acts of animal life, this is one of the chief, and moſt neceſſary. For whatſoever hath animal life, hath alſo the faculty of reſpiration, or ſomewhat equivalent thereto (*a*). Indeed

(*a*) The uſes aſſigned to *reſpiration* by all the anatomiſts before *Malpighi*'s diſcoveries of the ſtructure of the lungs, are ſo various, and many of them ſo improbable, that it would be frivolous to recount them. But the more eminent modern anatomiſts aſſign theſe uſes. *Willis* thus ſums up his opinion, *Præcipua pulmonum functio, & uſus ſunt, ſanguinem & aerem per totas partium compages, intimoſque receſſus, atque ductus quoſque minutiſſimos traducere, & ubique invicem committere; in eum nempe finem, ut ſanguis venoſus à circuitu redux, & chymo recenti dilutus, —tum perfectiùs miſceatur & velut ſubigatur, tum potiſſimùm ut ſecundum omnes ſuas partes ab aëre nitroſo de novo accendatur.*— "The principal function, and uſe of the lungs, is to tranſmit the blood, together with the air, through all the organs, and even into the moſt minute receſſes and ſmalleſt ducts, and thence to ſend it back again. So that the venous blood returning from its circuit, and diluted with the recent chyme, may be more perfectly mixed and prepared to be again vivified by the nitrous air."—*Pharmaceut.* p. 2. ſ. 1. c. 2. ſ. 2. *Mayow* ſaith rightly, that one grand uſe of *expiration* is, *Ut cum aëre expulſo, etiam vapores è ſanguine exhalantes, ſimul exſufflentur.*—"That together with the air breathed from the lungs, the vapours exhaling from the blood may be likewiſe expelled." And as for *inſpiration*, that it conveyeth a nitro-aerial ferment to the blood, to which the animal ſpirits are owing, and all muſcular motion. *Mayow de Reſpir.* p. 22, *&c. meâ edit.*

Somewhat

deed fo congenial is this with life, that *breath* and *life* are in fcripture phrafe and common fpeech

Somewhat of the opinion of thefe two laft cited, if I miftake not (it being long fince I read their tracts, and have them not now at hand,) were *Ent*, *Sylvius*, *Swammerdam*, *Diemerbroek*, and my friend Mr. *Ray*, in an unpublifhed tract of his, and his letters now in my hands.

But our Dr. *Thurfton*, for good reafons, rejects thefe from being principal ufes of *refpiration*, and thinks, with great reafon, the principal ufes to be to move, or pafs the blood from the right to the left ventricle of the heart. Upon which account perfons hanged, drowned, or ftrangled by catarrhs, fo fuddenly die, namely, becaufe the circulation of their blood is ftopped. For the fame reafon alfo it is, that animals die fo foon in the air-pump. Among other proofs he inftanceth in an experiment of Dr. *Croon*, *Profeff. Grefh.* which he made before our *R. S.* by ftrangling a pullet, fo that not the leaft fign of life appeared; but by blowing wind into the lungs through the *trachea*, and fo fetting the lungs a playing, he brought the bird to life again. Another experiment was once tried by Dr. *Walter Needham*, before Mr. *Boyle*, and others at *Oxford*, by hanging a dog, fo that the heart ceafed moving. But haftily opening the dog, and blowing wind into the *ductus Pecquetianus*, he put the blood in motion, and by that means the heart, and fo recovered the dog to life again. *V. Thurfton de Refpir. Uf.* p. 60, and 63. *meâ Edit.*

Such an experiment as Dr. *Croon*'s my friend, the late juftly renowned Dr. *Hook*, fhewed alfo our *R. S.* He cut away the *ribs*, *diaphragm*, and *pericardium*, of a dog; alfo the top of the wind-pipe, that he might tie it on to the nofe of a pair of bellows; and by blowing into the lungs, he reftored the dog to life; and then ceafing blowing, the dog would foon fall into dying fits; but by blowing again, he recovered; and fo alternately would die, and recover, for a confiderable time, as long, and as often as they pleafed. *Philof. Tranf.* No. 28.

For

ſpeech taken as ſynonymous things; or at leaſt, neceſſary concomitants of one another. *Moſes* (*b*) expreſſeth

For the farther confirmation of Dr. *Thurſton*'s opinion, the ingenious Dr. *Muſgrave* cut off, and cloſe ſtopped up the wind-pipe of a dog with a cork, and then threw open the *thorax*; where he found the blood ſtagnating in the *lungs*, the *arteria pulmonaris*, the *right ventricle*, and *auricle* of the *heart*, and the two great trunks of the *cava*, diſtended with blood to an immenſe degree; but at the ſame time, the *vena pulmonaris*, the *left ventricle*, and *auricle* of the *heart* in a manner empty, hardly a ſpoonful of blood therein. *Philoſ. Tranſ.* No. 240. Or both the experiments may be together met with in *Lowth. Abridg.* vol. iii. p. 66, 67.

This opinion of our learned *Thurſton*, the late learned *Etmullerus* eſpouſed, who being particular in reckoning up the uſes of reſpiration, I ſhall therefore the more largely cite him. Reſpiration, ſaith he, ſerves, 1. *Ad olfactum.* 2. *Ad ſcreatum & ſputationem.* 3. *Ad oſcitationem, tuſſim, ſternutationem, emunctionemque.* 4. *Ad liquidorum ſorbitionem, ſuctionemve.* 5. *Ad loquelam, cantum, clamorem, riſum, fletum, flatum, &c.* 6. *Ad fæcum alvi, urinæ, fœtûs molæve, necnon ſecundinarum expulſionem.* 7. *Ad promovenda ventriculi, inteſtinorum, lacteorumque vaſorum, &c. contenta.* 8. *Ad halitus aqueos ſanguinis è pulmonibus, aëris ope, exportandos.* 9. *Ad diapnoën.* 10. *Ad exactiorem chyli, lymphæque, necnon ſanguinis—miſcelam.* 11. *Ad conciliandum ſanguini—coccineam rubedinem, &c.* 12. *Nec moroſè negabimus, aërem—pulmones, & ſanguinem illos tranſcurrentem, minùs calida reddere, &c.* 13. *Quòd denique aër ſanguini ſingulis reſpirationibus aliquantillâ ſui parte, admixtus, pauciſſimas quaſdam in ſpirituum animalium elaboratione particulas ſimul contribuat.*— "1. For ſmelling. 2. For hawking and ſpitting. 3. For yawning, coughing, ſneezing, blowing the noſe. 4. For drinking and ſupping up liquors. 5. For ſpeaking, ſinging, crying, laughing, weeping, blowing, &c. 6. For propelling the feces by ſtool or urine, and for expelling the embryo, and the after-birth. 7. For promoting the motion of the contents of the ſtomach, inteſtines, and lacteals. 8. For carrying off from the lungs

expresseth animal-life, by *the breath of life.* Saith he, *Gen.* vii. 21, 22, *All flesh that moveth on the earth,*

lungs the watery particles imbibed by the blood. 9. For perspiration. 10. For the more perfect mixture of the chyle, the lymph, and the blood. 11. For giving the blood its florid red colour. 12. Nor can we deny that the air serves to cool the lungs and the blood passing through them. 13. And likewise that the air at each respiration, mixing itself a little with the blood, contributes in some degree to the elaboration of the animal spirits."—All these uses, although of great consequence, yet he thinks rather conduce to the *well-being*, than the being of the animal; because without any of them, the animal would not so speedily die, as it doth by strangling, or in the air-pump. He therefore assigns a 14th, and the principal use of respiration to be, *For the passing of the blood through the lungs, that is thrown into them by the heart.* Etmull. Dissert. ii. *c.* 10. *sect.* 1. and 16.

But the late Dr. *Drake*, with great ingenuity and address, (like a person so considerable for his years, as he was in his time,) not only established this notion of respiration, but also carries it farther, making it the true cause of the *diastole* of the heart; which neither *Borelle*, *Lower*, or *Cowper*, much less any before those great men, have well accounted for. That the heart is a muscle, is made evident beyond all doubt by Dr. *Lower*. And that the motion of all muscles consists in constriction, is not to be doubted also. By which means the systole is easily accounted for. But forasmuch as the heart hath no *antagonist-muscle*, the *diastole* hath puzzled the greatest wits. But Dr. *Drake* with great judgment, and much probability of reason, maketh the weight of the incumbent atmosphere to be the true *antagonist* to all the muscles, which serve both for ordinary inspiration, and the constriction of the heart. The particulars of his opinion may be seen in his *anatomy*, *l.* 2. *c.* 7. And in *Philos. Trans.* No. 281.

And I remember when I was at the university, my most ingenious and learned tutor Dr. *Wills*, when he read anatomy to us, was of opinion, that the lungs were blown up by the

earth, fowl, cattle, beast, creeping things, and man; all in whose nostrils was the breath of life in the dry land died. So the psalmist, *Psal.* civ. 29. *Thou takest away their breath, they die.* So grand an act therefore in common to all animals, may justly deserve a place in this survey of the works of God in the animal kingdom.

And here I might launch out into an ample description of all the parts ministring to this necessary act, and shew the curious contrivance, and artificial structure of them; but a transient view shall suffice. I might begin with the outward guards, the nose and mouth; but these have been already

weight of the incumbent air, and represented the manner of respiration in this manner, *viz.* he put a bladder into a pair of bellows, turning back the neck of the bladder, and tying it fast, so that no air might enter in between the bladder and bellows. This being done, when the bellows were opened, the bladder would be blown up by the weight of the incumbent air; and when shut, the air would be thereby pressed forcibly out of the bladder, so as to blow the fire. This experiment I take notice of here; because (besides the illustration it gives to respiration) that great *genius* seems to have had a truer notion of this *phænomenon,* than was very common then, *viz.* about the year 1677, or 1678; as also, because I have in some authors met with the same experiment, without mention of Dr. *Wills,* whose I take it to have been.

Another use of great consideration, the already commended Dr. *Cheyne* assigns; namely, to form the elastic globules of which the blood principally consists, without which there would be a general obstruction in all the capillary arteries. *Cheyne's Philosophical Prin. of Natur. Religion;* or *Harris's Lex. Tech. in Lungs.*

(*b*) *Gen.* ii. 7.—vi. 17. and vii. 15.

touched

touched upon. But the exquiſite mechaniſm of the *larynx*, its variety of muſcles, its cartilages, all ſo exquiſitely made for the purpoſe of reſpiration, and forming the voice (*c*), are very admirable: and no leſs ſo is the tongue (*d*), which miniſters to that, and many other uſes too.

Next,

(*c*) Becauſe it would be endleſs to ſpecify the curious mechaniſm of all the parts, concurring to the formation of the voice; I ſhall therefore for a ſample note only two things: 1. There are thirteen muſcles provided for the motion of the five cartilages of the *larynx*, *Gibſ. Anat.* l. 2. c. 14. a ſign of the careful and elaborate proviſion that is made for the voice. 2. It is a prodigious faculty of the *glottis*, in contracting and dilating itſelf with ſuch exquiſiteneſs, as to form all notes. *For* (as the ingenious Dr. *Keil* ſaith) *ſuppoſing the greateſt diſtance of the two ſides of the* glottis *to be one tenth part of an inch in ſounding twelve notes (to which the voice eaſily reaches); this line muſt be divided into twelve parts, each of which gives the aperture requiſite for ſuch a note, with a certain ſtrength. But if we conſider the ſub-diviſion of notes, into which the voice can run, the motion of the ſides of the* glottis *is ſtill vaſtly nicer. For if two chords ſounding exactly uniſons, one be ſhortened one two-thouſandth part of its length, a juſt ear will perceive the diſagreement, and a good voice will ſound the difference, which is one one hundred and ninety-ſixth part of a note. But ſuppoſe the voice can divide a note into a hundred parts, it follows that the different apertures of the* glottis *actually divide the tenth part of an inch into twelve-hundred parts, the effect of each of which produces a ſenſible alteration upon a good ear. But becauſe each ſide of the* glottis *moves juſt equally, therefore the diviſions are juſt double; or the ſides of the* glottis, *by their motion, do actually divide one tenth part of an inch into two thouſand four hundred parts.* Keil's Anat. *c.* 3. *ſect.* 7.

(*d*) Among the inſtruments of ſpeech, the tongue is a neceſſary one; and ſo neceſſary, that it is generally thought no

ſpeech

Next, the fabric of the (*e*) *trachea* deferves efpecial remark. Its valve, the *epiglottis* on the top,

fpeech can be without it. But in the third *tome* of the *Ephem. Germ.* is publifhed, *Jac. Rolandi Agloffoftomographia, five Defcriptio Oris fine Linguâ quod perfectè loquitur, & reliquas fuas functiones naturaliter exercet.* The perfon defcribed is one *Pet. Durand,* a *French* boy of eight or nine years old, who at five or fix loft his tongue by a *gangrene,* occafioned by the fmall pox: notwithftanding which, he could (as the title faith) fpeak perfectly, as alfo tafte, fpit, fwallow, and chew his food; but this latter he could do only on that fide he put it into, not being able to turn it to the other fide his mouth.

In the fame tract. *chap.* 6. is this obfervation of *ventriloquous* perfons; *Memini me à quodam fat celebri anatomico audiviffe, dum de duplicaturâ mediaftini ageret, fi membrana ifta duplex naturalitèr unita in duas partes dividatur, loquelam quafi ex pectore procedere, ut circumftantes credant dæmoniacum hunc, aut fternomythum.*—"I remember I was informed by a famous anatomift, in fpeaking of the doubling of the *mediaftinum,* that if that double membrane, which is naturally united, were divided into two parts, the fpeech would proceed from the breaft, fo that byftanders would believe the perfon to be either a demoniac or a ventriloquift."

(*e*) *The variation of the wind-pipe is obfervable in every creature, according as it is neceffary for that of the voice. In an* urchin, *which hath a very fmall voice, it is hardly more than membranous: and in a* pigeon, *which hath a low and foft note, it is partly cartilaginous, and partly membranous. In an* owl, *which hath a good audible note, it is more cartilaginous; but that of a* jay *hath hard bones inftead of cartilages; and fo of a* linnet: *whereby they have both of them a louder and ftronger note,* &c.

The rings of the wind-pipe are fitted for the modulation of the voice: for in dogs *and* cats, *which in the expreffion of divers paffions ufe a great many notes (as men do), they are open and flexible, as in man. Whereby all or any of them are dilated or contracted,*

top, to fence againſt all annoyances *; its cartilaginous rings (*f*) nearly environing it, with its membranous part next the gullet, to give the freer paſſage to the deſcent of the food. And laſtly, its inner tegument of exquiſite ſenſe to be readily affected with, and to make efforts againſt every

tracted, more or leſs, as is convenient for a higher or deeper note, &c. *whereas in ſome other animals, as in the* Japan peacock, *which uſeth hardly more than one ſingle note, they are entire,* &c. Grew's Coſmolog. Sacr. *book* i. *chap.* 5. *ſect.* 9, 10.

(*f*) It is a farther manifeſt indication of ſingular deſign in the cartilaginous rings of the *aſpera arteria*, that all the way where they are contiguous to the *œſophagus*, they are membranous, to afford an eaſy paſſage to the food; but after that, in the *bronchi*, they are, ſome completely annular, ſome triangular, *&c.* And another obſervable is, the lower parts of the ſuperior cartilages, receive the upper parts of the inferior in the *bronchi*; whereas in the *aſpera arteria*, the cartilages run and remain parallel to one another; which is a noble difference or mechaniſm in this (in a manner) one and the ſame part, enabling the lungs and *bronchi*, to contract themſelves in expiration, and to extend and dilate themſelves in inſpiration.

* Nothing can be more clearly demonſtrative of the deſign and wiſdom of the great Author of our being, than that exquiſite contrivance by which the food, in its way to the ſtomach, is made to paſs over the opening of the wind-pipe by means of the *epiglottis*, a ſmall cartilage, which, being preſſed down by the food in the action of ſwallowing, overlaps and covers the orifice of the wind-pipe, thus forming a bridge for its free paſſage, and riſing again by its natural ſpring as ſoon as the food has paſſed over it, in order to allow the inſpiration and expiration of the air from the lungs. EDITOR.

thing that is hurtful or offenſive; theſe, I ſay, do all juſtly deſerve our admiration.

And no leſs prodigious are the parts farther within; the *bronchi*, the *veſiculæ* (*g*), with their muſcular fibres (*h*), as ſome aſſert they have, together

(*g*) I ſhall not here intrench ſo much upon the anatomiſt's province, to give a deſcription of the *lungs*, although it be a curious piece of God's workmanſhip; but refer to ſeignior *Malpighi*, the firſt diſcoverer of their *veſiculæ* in 1660, in his two letters to *Borelli de Pulmon.* Alſo to Dr. *Willis*'s *Pharm. Rat.* p. 2. ſect. 1. cap. 1. *de Reſpir. Orig. & Uſ.* who as he wrote after *Malpighi*, ſo hath more accurately deſcribed thoſe parts; and to Mr. *Cowper's Anat.* tab. 24, 25. And if the reader hath a mind to ſee what oppoſition ſeignior *Malpighi*'s diſcoveries met with at home and abroad, and what controverſies he had on that account; as alſo his cenſures of Dr. *Willis*'s deſcription and figures, he may conſult *Malpighi*'s life written by himſelf, p. 4 to 21.

That the *lungs* conſiſt of *veſiculæ*, or *lobuli* of *veſiculæ*, admitting of air from the *bronchi*, is viſible, becauſe they may be blown up, cleanſed of blood, and ſo dried. But Mr. *Cowper* ſaith, he could never part the *lobuli* (ſo as to make Dr. *Willis*'s fig. 1. tab. 3, and 4.); ſo that probably the *veſiculæ* are contiguous to one another throughout each lobe of the lungs. And not only air, but *Diemerbroeck* proves that the *veſiculæ* admit of duſt alſo, from two aſthmatic perſons he opened; one a ſtone-cutter's man, the *veſiculæ* of whoſe lungs were ſo ſtuffed with duſt, that in cutting, his knife went as if through an heap of ſand; the other was a feather driver who had theſe bladders filled with the fine duſt or down of feathers.

(*h*) There is a conſiderable difference between Dr. *Willis* and *Etmuller*, *viz.* whether the *veſiculæ* of the lungs have any muſcular fibres or not? *Etmuller* expreſly ſaith, *Nullas fibras muſculoſas, multo minus rubicundam muſculorum compagem (ſunt enim*

gether with the arteries and veins, which every where accompany the airy paſſages, for the blood to receive there its impregnations from the air.

enim veſiculæ albidæ & fere diaphanæ) in inſis reperiri.—"That no muſcular fiſhes are to be found in them; much leſs the red *compages* of the muſcles; for the veſicles are white and almoſt tranſparent."—*Ubi ſupra*, c. 6. ſect. 2. And afterwards, ſect. 3. *Pulmones eſſe molles flexileſque, muſculoſis fibris ceu propriæ explicationis organis deſtitutos.*—"That the lungs are ſoft and flexible, and deſtitute of muſcular fibres, or the organs for unfolding or dilating themſelves."—But Dr. *Willis* as expreſly aſſerts, they have muſculous fibres, and aſſigns an excellent uſe of them; *Cellulæ iſtæ veſiculares, ut nixus pro expiratione contractivos edant, etiam fibras, uti per microſcopium planè conſpicere eſt, muſculares obtinent.*—"Theſe veſicular cells, as appears by the aid of a microſcope, have likewiſe muſcular fibres, in order that they may be able to make thoſe contractive efforts neceſſary for expiration."—*Ubi ſupra*, ſect. 16. And in the next ſection, *Ut pro datâ occaſione majorem aëris copiam exſufflent, aut materiam extuſſiendam ejiciant, fibris muſcularibus donatæ, ſeſe arctiùs contrahunt, contentaque ſua penitùs exterminant. Et enim ordinariæ pectoris ſyſtolæ, quas muſculorum relaxationes ex parte efficiunt, aërem forſan totum à tracheâ & bronchiis, haud tamen à veſiculis, quâque vice ejiciunt: propter has (quoties opus erit) inaniendas, & totius pectoris cavitas plurimùm anguſtatur, & cellulæ ipſæ veſiculares à propriis fibris conſtrictis coarctantur.*—"They are furniſhed with muſcular fibres, and contract themſelves occaſionally, in order to throw out a greater quantity of air, to eject the ſubſtance to be coughed up, and expel their contents, For the ordinary contractions of the breaſt, effected by the relaxation of the muſcles, are perhaps ſufficient to expel the air from the *trachea* and *bronchia*, but not from the veſicles: but, in order to empty them, not only the whole cavity of the breaſt is contracted, but the veſicular cells are conſtricted by their proper fibres."

From hence I might proceed to the commodious form of the ribs (*i*), the curious mechanism of the intercostal-muscles (*k*), the diaphragm, and

(*i*) *Circa hos motus [scil. pectoris dilatationem, &c.] divini conditoris mechanicen, ad regulas mathematicas planè adaptam, satis admirari non possumus; siquidem nullâ aliâ in re manifestiùs* Ὁ Θεὸς γεωμετρεῖν *videtur. Quippe cùm pectoris, tum ampliatio, tum coarctatio à quibusdam musculis (quorum munus unicum est contrahere) perfici debeat; res ita instituitur, ut costæ quæ thoracis, velut parallelogrammi oblongi versus cylindrum incurvati, latera efformant, in figuram modò quadratam, cum angulis rectis, pro pectoris ampliatione; modò in rhomboeidem, cum angulis acutis pro ejusdem contractione, ducantur, &c.*—"With regard to those motions (the dilatation of the breast, &c.) plainly adapted to mathematical rules, we cannot enough admire the art of our great Creator, for in no instance does it more clearly appear that the Almighty Being has followed the exactest rules of geometry. For as both the dilatation and contraction of the breast is performed by the means of certain muscles, whose office is solely to contract, it is so ordered that the ribs which form the sides of the *thorax*, like oblong parallelograms, curved somewhat in a cylindrical form, are in some respects of a square figure with right angles, for the dilatation of the breast; and in other respects rhomboidal with acute angles for its contraction."—*Willis, ubi supra*, sect. 28.

(*k*) For the structure of the *intercostals*, *midriff*, &c. I shall refer to Dr. *Willis*, and other anatomists. But Dr. *Drake* taxeth Dr. *Willis* with an error, in fancying there is an opposition in the office of the *intercostals*, by reason that the fibres of the *external* and *internal intercostals* decussate; that therefore the *external* serve to raise the ribs, the *internal* to draw them down. But Dr. *Drake* is of *Steno*'s and Dr. *Mayow*'s opinion, that notwithstanding the decussation of their fibres, the power they exert upon, and the motion they effect in the ribs, is one and the same.—*Drake's Anat.* l. 2. c. 7. and l. 4. c. 5. *Mayow de Respir.* c. 7.

all

all the other muſcles (*l*) miniſtering both to the ordinary, and extraordinary offices of reſpiration. But

(*l*) Although Dr. *Drake*, and ſome others, deny the *intercoſtals* being antagoniſt-muſcles, as in the preceding note; yet they, and moſt other anatomiſts that I have met with, attribute a conſiderable power to them in the act of reſpiration, as they do alſo to the *ſubclavian* and *triangular-muſcles*; but the learned *Etmuller* denies it for theſe three reaſons, 1. *Quia reſpirando nullam in illis contractionem ſentio.* 2. *Quia—ſibi invicem non adducuntur*, &c. 3. *Quia coſtæ omnes ab aliis modò enarratis muſculis moventur, idque ſimul*, &c. *Intercoſtales itaque, necnon ſubclavios muſculos coſtis, parietum inſtar, ad complenda interſtitia intercoſtalia, pectuſque integrandum, ac coſtas connectendas, intertectos eſſe, probabiliter concludo: quo munere triangulares etiam—fungi rationi conſentaneum eſt.*—" 1. Becauſe in reſpiring, I perceive no contraction in them. 2. Becauſe they are not brought cloſe to each. 3. Becauſe all the ribs are moved by the muſcles already deſcribed, and that at one and the ſame time. I therefore conclude, with ſome degree of probability, that the intercoſtals, and likewiſe the ſubclavian muſcles, are interwoven with the ribs, in order to fill up the interſtices between them, and connect the ribs together, which it is reaſonable to think is likewiſe the office of the triangular muſcles."—*Etmul. Diſſert.* ii. c. 4. ſect. 6.

But as to the uſe of the *triangular-muſcle* in reſpiration, we may judge of it, from its remarkable ſize and uſe in a dog; of which Dr. *Willis* gives this account from *Fallopius*: *In homine parvus adeò & ſubtilis iſte* [muſculus] *eſt, ut vix pro muſculo accipi queat: in cane per totum os pectoris protenditur, & cartilagines omnes, etiam verarum coſtarum ſterno inoſculatas, occupat: cujus diſcriminis ratio divinam circa animalium fabricas Providentiam planè indigitat. Quippe cùm hoc animal, ad curſus velociſſimos & diu continuandos natum, quo ſanguis, dum intenſiùs agitatur, ritè accendatur eventileturque, aërem celerrimè & fortiter uti inſpirare, ita etiam exſpirare debet—idcirco propter hunc actum firmiùs obeundum (cujus in homine haud magnus eſt uſus) muſculus caninus molem ingentem*

But paſſing them by, I ſhall ſtop at one prodigious work of Nature, and manifeſt contrivance of the Almighty Creator, which although taken notice of by others (*m*), yet cannot be eaſily paſſed by in the ſubject I am upon; and that is, the circulation of the blood in the *fœtus in the womb*, ſo different from the method thereof after it is born. In the womb, whilſt it is as one body with the mother, and there is no occaſion, nor place for reſpiration, there are two paſſages (*n*) on purpoſe for the tranſmiſſion

gentem & tanto operi parem ſortitur.—"In the human body that muſcle is ſo ſmall and ſlender, that it can ſcarcely be held as a muſcle; whereas in a dog it is extended over the whole breaſt bone, and embraces all the cartilages, even thoſe of the true ribs which are inſerted into the ſternum: the reaſon of which difference plainly points out the wiſdom of Almighty God in the ſtructure of animals. For as the dog is formed by nature for ſwift running and for a long continuance of it, ſo in order that the blood which is intenſely agitated, may be properly pervaded and cooled by the air, he is ſo formed as to inſpire and expire with great force and celerity; and for that purpoſe (which would be ſuperfluous in the human body) the canine muſcle is formed of a great ſize, and fitted to ſo great an exertion."—*Willis, ubi ſupra*, ſect. 32.

(*m*) Ray's *Wiſdom of God in the Creation*, p. 343.

(*n*) Mr. *Cheſelden*, an ingenious and moſt accurate anatomiſt, having ſomewhat particular in his obſervations about the circulation of the blood through the heart of the *fœtus*, I ſhall preſent the reader with ſome of his obſervations, which he favoured me with the ſight of. *The blood* (ſaith he) *which is brought to the heart by the aſcending* cava, *paſſes out of the right auricle into the left, through a paſſage called* foramen ovale, *in the* ſeptum [common to them both] *without paſſing through the right ventricle (as after the birth), while the blood from the deſcending* cava *paſſeth through*

miſſion of the blood without paſſing it through the lungs. But as ſoon as the *fœtus* is born, and become thereby a perfectly diſtinct being, and breathes for itſelf, then theſe two paſſages are ſhut up; one nearly obliterated, the other becomes only a ligament, except in ſome creatures that are amphibious, or are forced to lie long under water, in whom theſe paſſages probably remain open (*o*).

And

through the right auricle and ventricle into the pulmonary artery, and thence into the aorta *through the duct, betwixt that and the pulmonary artery, called* ductus arterioſus, *whilſt a ſmall portion of the blood, thrown into the pulmonary artery paſſeth through the lungs, no more than is ſufficient to keep open the pulmonary veſſels. Thus both ventricles are employed in driving the blood through the* aorta *to all parts of the* fœtus, *and to the mother too. But after the birth, the blood being to be driven from the* aorta *through the* fœtus *alone, and not the mother too, one ventricle becomes ſufficient, whilſt the other is employed in driving the blood through the lungs, the* ductus arterioſus *being ſhut up by means of the alteration of its poſition, which happens to it from the raiſing the* aorta *by the lungs, when they become inflated. After that the blood is thus driven into the lungs, in its return it ſhuts the* valve *of the* foramen ovale *againſt the* foramen *itſelf, to whoſe ſides it ſoon adheres, and ſo ſtops up the paſſage. The* ductus arterioſus, *or* ductus arterioſus in ligamentum verſus, *is ſeldom to be diſcerned in adult bodies, but the figure of the* foramen ovale *is never obliterated.*

(*o*) It hath been generally thought to be not improbable, but that on ſome occaſions the *foramen ovale* may remain open in man. In a girl of four or five years of age, Dr. *Connor* found it but half cloſed, and in the form of a creſcent. And he thinks ſomewhat of this kind might be in the perſon whoſe ſkeleton was found to have no joints in the back-bone, ribs, *&c.* Of which a deſcription, with cuts, may be found in *Phil. Tranſ.* No. 215. And more largely in his *Diſſert. Med. Phyſ. de ſtupendo*

And now what action of any rational creature, what is there in a man's life, that doth more plainly

pendo ossium coalitu, where he adds to the girl, in whom the *for. ov.* was not ſhut, a like obſervation of another girl he opened at *Oxford* of three years old: *In quâ foramen ovale ferè erat occluſum, in medio tamen, exili foramine, per quod turundam facilè tranſmiſi, erat pervium*, p. 30.—" In whom the *foramen ovale* was almoſt ſhut, but in the middle there was a ſmall opening through which I eaſily thruſt a probe."—So Mr. *Cowper* (than whom none more accurate and a better judge) ſaith, *I have often found the* foramen ovale *open in the adult*. Anat. Append. fig. 3. But Mr. *Cheſelden* is of a different opinion. Of which in the following note.

From ſomewhat of this cauſe, I am apt to think it was that the *Tronningholm* gardener eſcaped drowning, and ſome others mentioned by *Pechlin*. His ſtories are, *Hortulanus Tronningholmenſis etiamnum vivens, annos natus* 65, *pro illâ ætate ſatis adhuc valens & vegetus, cùm ante* 18 *annos, alii in aquas delapſo opem ferre vellet, forte fortunâ & ipſe per glaciem incautiùs procedens, aquas incidit* 18 *ulnas profundas: ubi ille, corpore erecto quaſi ad perpendiculum, pedibus fundo adhæſit. Conſtitit ſic per* 16 *horas, antequàm produceretur in auras. Dixit autem, ſimul ac infra aquarum ſuperficiem fuit demerſus, ſtatim obriguiſſe totum, &, ſi quem tum habuit motum & ſenſum, amiſiſſe, niſi quod ſonantes Stockolmii campanas etiam ſub aquis obſcuriùs percipere ſibi ſit viſus. Senſit etiam, ſtatim ſeſe velut veſiculam ori applicâſſe, adeò ut aqua nulla os penetraverit, in aures verò tranſitum, etiam ſentiente illo, habuerit; atque inde auditum ſuum debilitatum aliquandiu eſſe. Hoc ſtatu dum* 16 *horas permanſit fruſtrà quæſitus, tandem repertum, conto in caput infixo, cujus etiam ſenſum ſe habuiſſe dixit, fundo extraxerunt, ſperantes ex more aut perſuaſione gentis revicturum eſſe. Itaque pannis linteiſque productum obvolvunt, ne aër admitti poſſit pernicioſus futurus ſubito illapſu: cuſtoditum ſic ſatis ab aëre ſenſim ſenſimque tepidiori loco admovent; mox calidis adoriuntur faſciis, fricant, radunt, & ſufflaminatum tot horis ſanguinis corporiſque motum negotioſâ illâ operâ reducunt: denique antapoplecticis & genialibus liquoribus vitæ reddunt & priſtinæ*

plainly ſhew deſign, reaſon, and contrivance, than this very act of nature doth the contrivance and deſign

priſtinæ mobilitati. Retulit is atque oſtendit ſe etiamnum in capite circumferre veſtigia violentiæ à conto illatæ, & cephalalgiis vexari graviſſimis. Et propter hunc ipſum caſum, religiosè à popularibus, & hujuſce rei teſtibus probatum, ſereniſſimæ reginæ matris munificentiâ & annuo ſtipendio eſt donatus—& ſereniſ. principi—oblatus, vivus ſui teſtis—Conſignatam manu habes hiſtoriam D. Tilaſii, biblioth. reg. præfecti, qui teſtatus eſt ſe prænoviſſe mulierem, quæ tres ipſos dies ſub aquis hæſit, & ſimilem in modum, quo hortulanus ille, reſuſcitata, adhuc dum lucis plenâ fruitur uſurâ. Accedit nob. Burmanni—fides, qui confeſſus eſt,—ſe in pago Boneſs *parochiæ* Pithoviæ *concionem frequentâſſe funebrem, in quâ, dum acta recenſeret præco ſenis cujuſdam ſeptuagenarii* Laur. Jonæ—*audiverit ex ore concionatoris, vivum eum, adoleſcentem* 17 *annorum, aquis ſubmerſum,* 7 *demum hebdomadâ (rem prodigioſam!) extractum ad ſe rediiſſe vivum & incolumem.*—
" A gardener of Tronningholm who is yet alive, and is 65 years of age, of a freſh and vigorous conſtitution for that time of life, about 18 years ago, in endeavouring to aſſiſt a man who had fallen into the water, fell in himſelf through the ice where the water was 18 ells in depth, and ſtuck with his feet in the mud at the bottom, ſtanding in an erect poſture. He remained ſo for 16 hours before he was brought up. He told that as ſoon as he had ſunk below the ſurface of the water, he grew immediately ſtiff, and loſt all ſenſe and motion, unleſs it was a faint perception of ſtill hearing, as he thought, under water, the bells of Stockholm. He felt likewiſe as it were a bladder applied to his mouth, which prevented the entrance of the water, which however he felt coming in at his ears, and thence he ſuppoſes his hearing was weakened. Remaining in this ſtate, he was ſearched for to no purpoſe for 16 hours; at length being found, he was dragged from the bottom by a pole fixed in his head, of which he remembered the feeling while in the water. The people as uſual had hopes of recovering him, and having wrapt the body in warm clothes, to keep it from the ſudden influence of the air, and removed it by degrees from a cooler to a warmer place, they then applied

deſign of the great GOD of Nature? What is thought and contrivance, if this be not? Namely, That

applied heated coverings, rubbed the body, blew into it, and at length in the ſpace of ſome hours they brought back the vital motion and the circulation of the blood. Then adminiſtering antapoplectic and cordial liquors, they reſtored him entirely to life. He ſhewed the mark on his head from the ſtroke of the pole, and was for ſome time much afflicted with violent headaches. On account of this accident, which was proved by the teſtimony of all the neighbourhood, he had an annual penſion conferred on him by the bounty of the queen-mother, and being preſented to the prince, bore teſtimony himſelf to what had happened to him. The ſtory is vouched under the hand of Tillarius, the king's librarian, who likewiſe bears witneſs that he knew a woman who had remained for three days under water, who was brought to life in the ſame manner as the gardener of Tronningholm, and who is yet alive. To this is added the teſtimony of Burman, who declares that in a funeral ſermon in the pariſh church of Pithou, of an old man of 70, he heard the preacher relate that the ſame man, when a youth of 17 years of age, had been drowned and remained under water ſeven weeks, (a prodigy indeed!) and being afterwards drawn out, had moſt miraculouſly recovered.—*Pechlin. de Aer. & Alim. def.* c. 10.

Shall we to this cauſe, or to the oſſification, or more than ordinary ſtrength of the wind-pipe, attribute the recovery to life of perſons hanged? Of which *Pechlin* gives an inſtance that fell under his own knowledge, of a woman hanged, and in all appearance dead, but recovered by a phyſician accidentally coming in, by a plentiful adminiſtration of *ſpir. ſal. armon.* Pechl. ib. c. 7. And the ſtory of *Anne Green*, executed at *Oxford, Dec.* 14. 1650, is ſtill well remembered among the ſeniors there. *She was hanged by the neck near half an hour, ſome of her friends in the meantime thumping her on the breaſt, others hanging with all their weight upon her legs, ſometimes lifting her up, and then pulling her down again with a ſudden jerk; thereby the ſooner to diſpatch her out of her*

 pain;

That there ſhould be a temporary part in the body, made juſt for the preſent exigence; to continue whilſt there is occaſion for it, and to ceaſe when there is none; in ſome creatures to remain always, by reaſon of their amphibious way of living, and in land-animals (purely ſuch) to ceaſe.

Another excellent contrivance, a-kin to the laſt, is, for the preſervation of ſuch creatures whoſe occaſions frequently neceſſitate them to live without, or with but little reſpiration: fiſhes might be named here, whoſe habitation is always in the waters; but theſe belong to an element which I cannot at preſent engage in. But there are many animals of our own element, or partly ſo, whoſe organs of reſpiration, whoſe blood, whoſe heart, and other inſtruments of life, are admirably accommodated to their method of living: thus many amphibious creatures (*p*), who live in water as well as

pain; as her printed account wordeth it. After ſhe was in her coffin, being obſerved to breathe, a luſty fellow ſtamped with all his force on her breaſt and ſtomach, to put her out of her pain. But by the aſſiſtance of Dr. *Peity*, Dr. *Willis*, Dr. *Bathurſt*, and Dr. *Clark*, ſhe was again brought to life. I myſelf ſaw her many years after, after that ſhe had (I heard) born divers children. The particulars of her crime, execution, and reſtoration, ſee in a little pamphlet, called *News from the Dead*, written, as I have been informed, by Dr. *Bathurſt* (afterwards the moſt vigilant and learned preſident of *Trinity College, Oxon.*), and publiſhed in 1651, with verſes upon the occaſion.

(*p*) The *ſea-calf* hath the *foramen ovale*, by which means it is enabled to ſtay long under the water, as the *Pariſ. anatomiſts*. Of which ſee in *book* vi. *chap.* 5. *note* (*c*).

But

as air; many quadrupeds, birds, insects, and other animals, who can live some hours, days, yea, whole winters, with little or no respiration, in a torpitude, or sort of sleep, or middle state between life and death: the provision made for these peculiar occasions of life, in the fabric of the lungs, the heart, and other parts of such creatures (*q*), is manifestly the work of Him, who as St. *Paul* saith (*r*) *Giveth to all breath, and life, and all things.*

But the fore-commended Mr. *Cheselden*, thinks the *foramen ovale* is neither open in amphibious creatures, nor any adult land-animals. *When I first* (saith he) *applied myself to the dissection of human bodies, I had no distrust of the frequent accounts of the* foramen ovale *being open in adults; but I find since, that I mistook the* ostium venarum coronariarum *for the* foramen. *The like I suppose authors have done, who assert that it is always open in amphibious animals; for we have made diligent enquiry into those animals, and never found it open. Neither would that (as they imagine) serve these creatures to live under water, as the* fœtus *doth* in utero, *unless the* ductus arteriosus *was open also.*

This opinion of Mr. *Cheselden* hath this to render it probable, That the *ostium venarum coronariarum* is so near the *foramen ovale*, that without due regard, it may be easily mistaken for it. Such therefore as have opportunity of examining this part in amphibious animals, or any other subject, ought to seek for the *ostium*, whenever they suspect they have met with the *foramen.*

(*q*) Of the singular conformation of the heart and lungs of the *tortoise*, which is an amphibious animal, see *book* vi. *chap.* 5. *note* (*b*).

(*r*) *Acts* xvii. 25.

CHAP. VIII.

Of the Motion of Animals.

NEXT to the two grand acts of animal life, their fenfe or refpiration, I fhall confider their *motion*, or *locomotive faculty*; whereby they convey themfelves from place to place, according to their occafions and way of life: and the admirable apparatus to this purpofe, is a plain demonftration of God's particular forefight, care, and efpecial Providence towards all the animal world.

And here I might view, in the firft place, the mufcles, their curious ftructure (*a*), the nice tack-

(*a*) That the mufcles are compounded of fibres, is vifible enough. Which fibres, the curious and ingenious *Borelli* faith, are cylindraceous; not hollow, but filled with a fpungy, pithy fubftance, after the manner of elder, as he difcovered by his microfcopes. *Borel. de Mot. Animal.* Part 1.

Thefe fibres, he faith, are naturally white; but derive their rednefs only from the blood in them.

Thefe fibres do in every mufcle (in the belly at leaft of the mufcle) run parallel to one another, in a neat orderly form. But they do not at all tend the fame way, but fome run aflant, fome long-ways, *&c.* according to the action or pofition of each refpective mufcle. The particulars of which, and of divers other obfervables in the mufcles, would, befides figures, take up too much room in thefe notes; and therefore I muft refer to the anatomifts, particularly *Steno*, *Borelli*, *Cowper*, *&c.*

ing

ing them to every joint, to pull it this way, and that way, and the other way, according to the special purpose, design, and office of every such joint: also their various size and strength; some large and corpulent, others less, and some scarce visible to the naked eye; all exactly fitted to every place, and every use of the body. And lastly, I might take notice of the muscular motions, both involuntary and spontaneous (*b*).

Next, I might survey the special fabric of the bones (*c*), ministering to animal motion. Next, I might

(*b*) The infinite Creator hath generally exerted his art and care, in the provision made by proper muscles and nerves, for all the different motions in animal bodies, both involuntary and voluntary. It is a noble Providence, that most of the vital motions, such as of the heart, stomach, guts, *&c.* are involuntary, the muscles acting whether we sleep or wake, whether we will or no. And it is no less providential that some, even of the vital motions, are partly voluntary, partly involuntary, as that, for instance, of breathing, which is performed both sleeping and waking; but can be intermitted for a short time on occasion, as for accurate hearing any thing, *&c.* or can be increased by a stronger blast, to make the greater discharges of the blood from the lungs, when that any thing overcharges them. And as for the other motions of the body, as of the limbs, and such as are voluntary, it is a no less providence, that they are absolutely under the power of the will; so as that the animal hath it in his power to command the muscles and spirits, or any part of its body, to perform such motions and actions as it hath occasion for.

(*c*) *Quid dicam de ossibus? quæ subjecta corpori mirabiles commissuras habent, & ad stabilitatem aptas, & ad artus finiendos accommodatas, & ad motum, & ad omnem corporis actionem.*—" What shall we say of the bones, of which the joinings are so admirably adapted

might take notice of the joints (*d*), their complete form adjusted to the place, and office they are

adapted both for strength, for motion, and for every action of the body."—*Cicer. de Nat. Deor.* l. 2. c. 55.

By reason it would be endless to mention all the curiosities observable in the bones, I shall for a sample, single out only an instance or two, to manifest that design was used in the structure of these parts in man.

The first shall be in the *back-bone*, (see Plate A, fig. 2.) which among many others hath these two things remarkable. 1. Its different articulations from the other joints of the body. For here most of the joints are flat, and withal guarded with asperities and hollows, made for catching and holding; so as firmly to lock and keep the joints from luxations, but withal to afford them such a motion, as is necessary for the incurvations of the body. 2. The difference of its own joints in the neck, back, and loins. In the neck, the *atlas*, or upper *vertebra*, as also the *dentata*, are curiously made, and jointed (differently from the rest) for the commodious and easy bending and turning the head every way. In the *thorax*, or back, the joints are more close and firm; and in the loins, more lax and pliant; as also the spines are different, and the knobs and sockets turned the quite contrary way, to answer the occasions the body hath to bend more there than higher in the back. I shall close this remark with the ingenious Dr. *Keil's* Observation.

The structure of the spine *is the very best that can be contrived; for had it been all bone, we could have had no motion in our backs; had it been of two or three bones articulated for motion, the* medulla spinalis *must have been necessarily bruised at every angle or joint; besides, the whole would not have been so pliable for the several postures we have occasion to put ourselves in. If it had been made of several bones without intervening cartilages, we should have had no more use of it, than if it had been but one bone. If each* vertebra *had had its own distinct cartilages, it might have been easily* dislocated. *And lastly, The oblique processes of each superior and inferior* vertebra, *keep the middle one that it can neither be thrust backwards nor forwards*

are employed in; their bandage, keeping them from luxations; the oily matter (*e*) to lubricate them,

forwards to compreſs the medulla ſpinalis. Keil's Anat. cap. 5. ſect. 8.

Compare here what *Galen* ſaith of the articulations, ligaments, perforation, *&c.* of the *ſpine*, to prove the wiſdom and providence of the Maker of animal bodies, againſt ſuch as found fault with Nature's works; among which he names *Diagoras*, *Anaxagoras*, *Aſclepiades*, and *Epicurus*. Vide *Galen. de Uſ. Part.* l. 12. init. and c. 11, *&c.* alſo l. 13. init.

2. The next inſtance ſhall be in one or two things, wherein the ſkeletons of the two ſexes differ. Thus the *pelvis* made in the belly by the *ilium*, *oſſa coxendicis*, and *pubis*, is larger in a female than male ſkeleton, that there may be more room for the lying of the *viſcera* and *fœtus*. So the cartilage bracing together the two *oſſa pubis* or *ſharebones*, *Bartholine* ſaith, is twice thicker and laxer in women than men: as alſo is the cartilage that tieth the *os ſacrum* to its *vertebra*; and all to give way to the paſſage of the *fœtus*.

Another conſiderable difference is in the cartilaginous production of the ſeven long ribs, whereby they are braced to the breaſt-bone. Theſe are harder and firmer in women than in men; the better to ſupport the weight of the breaſts, the ſucking infant, *&c.*

(*d*) It is remarkable in the joints, and a manifeſt act of caution and deſign: 1. That although the motion of the limbs be circular, yet the centre of that motion is not in a point, but an ample ſuperficies. In a point, the bones would wear and penetrate one another; the joints would be exceedingly weak, *&c.* but the joints conſiſting of two large ſuperficies, concave and convex, ſome furrowed and ridged, ſome like a ball and ſocket, and all lubricated with an oily ſubſtance, they are incomparably prepared both for motion and ſtrength. 2. That the bones next the joint are not ſpungy, as their extremities commonly are, not hard and brittle, but capped with a ſtrong, tough, ſmooth,

Fig. 1.

Fig. 2.

Fig. 1. Front view of the human Skeleton. Shewing the Fabrik & disposition of the Bones.
Fig. 2. the Structure of the Spine.

them, and their own ſmoothneſs to facilitate their motion.

ſmooth, cartilaginous ſubſtance, ſerving both for ſtrength and motion.

But let us here take notice of what *Galen* mentions on this ſubject. *Articulorum unuſquiſque eminentiam cavitati immiſſam habet: veruntamen hoc fortaſſe non adeò mirabile eſt: ſed ſi, conſideratâ omnium totius corporis oſſium mutuâ connexione, eminentias cavitatibus ſuſcipientibus æquales ſemper inveneris; hoc mirabile. Si enim juſto amplior eſſet cavitas, laxus ſanè & infirmus fieret articulus; ſi ſtrictior, motus difficulter fieret, ut qui nullam verſionem haberet; ac periculum eſſet non parvum, eminentias oſſium arctatas frangi: ſed horum neutrum factum eſt.—Sed quoniam ex tam ſecurâ conſtructione periculum erat, nè motiones difficiliùs fierent, & eminentiæ oſſium extererentur, duplex rurſus auxilium in id Natura molita eſt. 1. Cartilagine os utrumque ſubungens, atque oblinens: alterum, ipſis cartilaginibus humorem unctuoſum, velut oleum, ſuperfundens; per quem facilè mobilis, & attritu contumax omnis articulatio oſſium facta eſt.—Ut undique diligenter articulus omnis cuſtodiretur, ligamenta quædam ex utroque oſſe produxit Natura.*—" Each of the joints has a large round extremity inſerted into a cavity. Perhaps this does not appear ſo wonderful; but if we conſider the mutual connection of all the bones of the body, we ſhall find theſe projecting extremities always preciſely equal to the cavities. This is indeed admirable: for obſerve, were the cavity larger than the extremity, the joint itſelf would be looſe and weak; were it ſmaller, the joint could not move or turn with eaſe, and there would be a danger of the ends of the bones breaking: but both theſe extremes are avoided. Moreover, leſt from ſo nice and compact a ſtructure there ſhould be either a difficulty of motion or a danger of the bones being worn, Nature has furniſhed a double contrivance. 1. Each bone is protected by a cartilage, and 2. Theſe cartilages are moiſtened by an unctuous and oily liquor, rendering the joint eaſy to be moved, and ſafe againſt friction. Beſides theſe contrivances for guarding the joint, certain ligaments are extended from each bone."—*Galen de Uſ. Part.* l. 1. c. 15.

And laſtly, I might trace the various nerves throughout the body, ſent about to miniſter to its various motions (*f*). I might conſider their ori-

(*e*) For the affording this oily or mucilaginous matter, there are *glandules* very commodiouſly placed near the joints, ſo as not to ſuffer too great compreſſion by the motion of the neighbouring bones, and yet to receive a due preſſure, ſo as to cauſe a ſufficient emiſſion of the mucilage into the joints. Alſo, another thing conſiderable is, that the excretory ducts of the *mucilaginous glands* have ſome length in their paſſage from the glands to their mouths; which is a good contrivance, to prevent their mouths being oppreſſed by the mucilage, as alſo to hinder the too plentiful effuſion thereof, but yet to afford a due expreſſure of it at all times and on all occaſions, as particularly in violent and long continued motions of the joints, when there is a greater than ordinary expence of it. See *Cowper's Anat. Tab.* 79.

(*f*) There is no doubt to be made, but that the muſcles receive their motion from the nerves. For if a nerve be out, or ſtreightly bound, that goes to any muſcle, that muſcle ſhall immediately loſe its motion. Which is doubtleſs the caſe of paralytics; whoſe nerves are ſome of them by obſtructions, or ſuch like means reduced to the ſame ſtate as if cut or bound.

And this alſo is the cauſe of that *numbneſs* or *ſleepineſs* we find oftentimes, by long ſitting or lying on any part.

Neither is this a modern notion only; for *Galen* ſaith, *Principium nervorum omnium cerebrum eſt, & ſpinalis medulla.—Et nervi à cerebro animalem virtutem accipiunt—Nervorum utilitas eſt facultatem ſenſûs & motûs à principio in partes diducere.*—" The brain and the ſpinal marrow is the beginning of all the nerves. The nerves receive their animal virtue from the brain. The uſe of the nerves is to communicate feeling and motion from their primary ſeat, through all the parts of the body."—And this he intimates to have been the opinion of *Hippocrates* and *Plato*, de Uſ. Part. l. 1. c. 16. & paſſim.

gin

gin (*g*), their ramifications to the feveral parts, and their inofculations with one another, according to the harmony and accord of one part with another, neceffary for the benefit of the animal. But fome of thofe things I have given fome touches upon already, and more I fhall mention hereafter (*h*), and it would be tedious here to infift upon them all.

I fhall therefore only fpeak diftinctly to the locomotive act itfelf, or what directly relates to it.

And here it is admirable to confider the various methods of Nature (*i*), fuited to the occafions of various animals. In fome their motion is fwift, in others flow. In fome performed with two, four,

(*g*) Dr. *Willis* thinks, that in the *brain* the fpirits are elaborated that minifter to voluntary motion; but in the *cerebellum*, fuch as effect involuntary, or natural motions; fuch as that of the heart, the lungs, &c. *Cerebri Anat.* c. 15.

(*h*) See *book* v. chap. 8.

(*i*) To the foregoing, I fhall briefly add fome examples of the fpecial provifion made for the motion of fome animals by *temporary parts*. *Frogs* and *toads*, in their tadpole-*ftate*, have tails, which fall off when their legs are grown out. The *lacerta aquatica*, or *water-newt*, when young, hath four neat ramified fins, two on a fide, growing out a little above its forelegs, to poife and keep its body upright, (which gives it the refemblance of a young fifh,) which fall off when the legs are grown. And the *nympha* and *aureliæ*, of all or moft of the infects bred in the waters, as they have particular forms, different from the infects they produce; fo have alfo peculiar parts afforded them for their motion in the waters: oars, tails, and every part adapted to the waters, which are utterly varied in the infects themfelves, in their *mature ftate* in the air.

or more legs; in ſome with two, or four wings; in ſome with neither (*k*).

And firſt for ſwift or ſlow motions. This we find is proportional to the occaſions of each reſpective animal. *Reptiles*, whoſe food, habitation, and neſts, lie in the next clod, plant, tree, or hole, or can bear long hunger and hardſhip, they need neither legs nor wings for their tranſportation; but their vermicular or ſinuous motion (performed with no leſs art, and as curiouſly provided for as the legs or wings of other creatures; this, I ſay) is ſufficient for their conveyance.

Man and *beaſts*, whoſe occaſions require a large room, have accordingly a ſwifter motion, with proper engines for that ſervice; anſwerable to their range for food, their occupation of buſineſs, or their want of armature, and to ſecure them againſt harms (*l*).

But

(*k*) *Jam verò alia animalia gradiendo, alia ſerpendo, ad paſtum accedunt, alia volando, alia nando.*—" Some animals ſeek their food in walking, others in creeping, others in flying, and others again in ſwimming."—*Cic. de Nat. Deor.* l. 2. c. 47.

Compare alſo what *Galen* excellently obſerves concerning the number of feet in man, and in other animals; and the wiſe proviſion thereby made for the uſe and benefit of the reſpective animals. *De Uſ. Part.* in the beginning of the third book.

(*l*) As I ſhall hereafter ſhew, that the indulgent Creator hath abundantly provided for the ſafety of animals by their cloathing, habitations, ſagacity and inſtruments of defence; ſo there appears to be a contemperament of their *motion* with theſe proviſions. They that are well armed and guarded, have commonly a ſlower motion; whereas they that are deſtitute thereof, are

But for the winged creatures (birds and infects), as they are to traverfe largs tracts of land and water, for their food, for their commodious habitation, or breeding their young, to find places of retreat and fecurity from mifchiefs; fo they have accordingly the faculty of flying in the air; and that fwiftly or flowly, a long or a fhort time, according to their occafions and way of life. And accordingly their wings, and whole body, are curioufly prepared for fuch a motion; as I intend to fhew in a proper place (*m*).

Another remarkable thing in the motive faculty of all creatures, is the neat, geometrical performance of it. The moft accurate mathematician, the moft fkilful in mechanic motions, cannot prefcribe a nicer motion (than what they perform) to the legs and wings of thofe that walk or fly (*n*), or to the bodies of thofe that creep (*o*). Neither can the body be more completely poifed for the motion it is to have in every creature, than it already actually is. From the largeft elephant to the fmalleft mite, we find the body artfully balanced (*p*). The head not too heavy, nor too light

are fwifter. So alfo timid helplefs animals are commonly fwift; thus deer and hares: but animals endowed with courage, craft, arms, &c. commonly have a flower motion.

(*m*) See *book* vii. chap. 1.

(*n*) See *book* vii. *chap.* 1. the end.

(*o*) See *book* ix. *chap.* 1. *note* (*c*).

(*p*) *Siquis unquam alius opifex, æqualitatis & proportionis magnam habuit providentiam, certè Natura habuit in animalium corporibus*

light for the reſt of the body, nor the reſt of the body for it (*q*). The *viſcera* are not let looſe, or ſo placed, as to ſwag, over-balance, or over-ſet the body; but well-braced, and diſtributed to maintain the æquipoiſe of the body. The motive parts alſo are admirably well fixed in reſpect to the center of gravity; placed in the very point, fitteſt to ſupport and convey the body. Every leg beareth its true ſhare of the body's weight. And the wings ſo nicely are ſet to the center of gravity, as even in that fluid *medium*, the air, the body is as truly balanced, as we could have balanced it with the niceſt ſcales.

ribus conformandis; unde Hippocrates eam rectiſſimè juſtam nominat.—"If ever artiſt ſhowed in his works an attention to ſymmetry and proportion, certainly Nature has done ſo in the ſtructure of the bodies of animals: with good reaſon then has Hippocrates termed her the moſt accurate artificer."—*Galen de Uſ. Part.* l. 2. c. 16.

(*q*) The make of the bodies of ſome water-fowl, ſeems to contradict what I here ſay, the heads and long necks of ſome, as of ſwans, ducks, and geeſe; and the hinder parts of others, as of the doucker and moor-hen, and ſome other kinds, ſeeming to be too heavy for the reſt of their body. But inſtead of being an argument againſt, it is a notable inſtance of, the Divine art and providence, theſe things being nice accommodations to their way of life. Of ſuch as have long necks, ſee *book* vii. *chap.* 2. *note* (*i*).

And as for ſuch whoſe hinder parts ſeems to over-balance their foremoſt parts, whereby they fly with their bodies in a manner erect, this alſo is an excellent accommodation to their way of life, which is diving rather than flying. Vide *book* vii, *chap.* 4. *note* (*k*).

But

But among all creatures, none more elegant than the ſizing the body of *man*, the gauging his body ſo nicely, as to be able to ſtand erect, to ſtoop, to ſit, and indeed to move any way, only with the help of ſo ſmall a ſtay as the feet (*r*): whoſe mechaniſm of bones, tendons, and muſcles to this purpoſe, is very curious and admirable.

(*r*) See *book* v. *chap.* 2. *note* (*h*).

CHAP. IX.

Of the Place allotted to the ſeveral Tribes of Animals.

HAVING diſpatched the motion of animals, let us in the next place conſider the *Place* which the infinitely wiſe Creator hath appointed them to move and act, and perform the offices of the creation in. And here we find every particular well ordered. All parts of our terraqueous globe fit for an animal to live and act in, are ſufficiently ſtocked with proper inhabitants: the watery element (unfit, one would think, for reſpiration and life) abounding with creatures fitted for it; its bowels abundantly ſtored, and its ſurface well beſpread. The earth alſo is plentifully ſtocked in all its parts, where animals can be of any uſe *, not probably

* A German profeſſor, Mr. ZIMMERMAN, in a very curious work, intitled *Specimen Zoologiæ Geographicæ*, has found a moſt ingenious method of exhibiting to the eye the various tribes and ſpecies of animals with which the earth is peopled, and the climates and countries which the different ſpecies inhabit. He gives a map of the world, in which, inſtead of towns and remarkable places, the names of the different animals occupy the ſeveral regions where they are in reality to be found. This plan is confined to the different ſpecies of quadrupeds: but the ſame idea may be purſued, not only in the other claſſes of animals, ſuch as reptiles, birds, fiſhes, &c. but may be extended to the

probably the deepeſt bowels thereof indeed, being parts in all likelihood unfit for habitation and
action,

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the vegetable and mineral kingdoms. In this way a ſet of phyſical maps might be conſtructed, which would be of eminent uſe in the ſtudy of natural hiſtory. I have for the reader's ſatisfaction given in the annexed plate a copy of a part of Mr. Zimmerman's map, including Europe, with a portion of Aſia and Africa. The animals are named according to the nomenclature of Linnæus: but the ſmallneſs of the ſcale of the original rendering various abbreviations neceſſary, theſe are explained in the following ſhort table.

The ABBREVIATIONS *of Mr.* ZIMMERMAN'S *Phyſical Map explained.*

A. aſinus, *Aſs*
Ant. antil. 1. antilope leucophæa, *Antelope*
Ant. 2. antilope bezoartica
Ant. 3. ——— oryx
Ant. 4. ——— ſcripta
Ant. 5. ——— grymmia
Ant. 6. cervula parva Afric.
Ant. 7. antilope tragocamelus
Ant. 8. ——— leucopus
Ant. 9. ——— dama
Ant. 10. ——— redunca
Ant. 11. ——— ſtrepſiceros
Ant. 12. ——— cervicapra
Ant. 13. ——— dorcas
Ant. 14. ——— kevella
Ant. 15. ——— tzeiran
Ant. 16. ——— ſcythica
Ant. 17. ——— bubalis
Ant. 18. ——— roba
Antil. var. antilopæ variæ
Ap. aper, *Boar*

B. bos, *Ox*
Bubal. bubalis, *Buffalo*
C. canis, *Dog*
Capre. capreolus, *Roe*
Cp. capra, *Goat*
Ct. cattus. *Cat.* Ct. f. cattus ferinus
Cerv. cervus, *Stag*
Cun. cuniculus, *Rabbit*
Dm. dama, *Doe*
E. equus, *Horſe*
Erin. erinaceus, *Hedge-hog*
Inuus. ſimia inuus
L. lupus, *Wolf*
Le. lepus, *Hare*
M. 1. mus amphibius, *Mouſe*, &c.
M. 2. mus rattus, *Rat*
M. 3. ſturmulot
M. 4. mus muſculus
M. 5. mus terreſtris
M. 6. mus ſylvatuus
M. 7. mus ſylvaticus minor.

M. 8.

action, and where a living creature would be uſeleſs in the world; but the ſurface every where abundantly ſtored †.

But

M. 8. mus gregarius vel ſocialis
M. 10. mus agrarius
M. 11. mus minutus
M. 12. mus avellanarum
M. 14. mus quercinus
M. 15. mus tamariſcinus
Muſt. muſtela, *Weaſel*
O. ovis, *Sheep*
Putor. muſtela putorius, *Polecat.*
S. ſus, *Sow*
Sc. ſciurus vulgaris, *Squirrel*
Sc. vel ſciurus volans
T. talpa vulgaris, *Mole*
T. c. talpa caudata
Tax. taxus ſeu meles
V. vulpes, *Fox*
Veſp. 1. veſpertilio vampirus
Veſp. 2. ——— ſpectrum, *Bat*
Veſp. 3. ——— haſtatus
Veſp. 4. veſpertilio perſpicillatus
Veſp. 5. ——— ſpaſma
Veſp. 6. ——— ſoricinus
Veſp. 7. ——— leporinus
Veſp. 8. ——— moloſſus
Veſp. 9. ——— nigrita
Veſp. 10. ——— barbatus
Veſp. 11. ——— pictus
Veſp. 12. ——— canadenſis
Veſp. 13. ——— cephalotes
Veſp. 14. ——— murinus
Veſp. 15. ——— noctula
Veſp. 16. ——— ſolea
Veſp. 17. ——— auritus
Veſp. 18. ——— ſerotinus
Veſp. 19. ——— pipiſtrellus
Veſp. 20. ——— barbaſtelus
Veſp. 21. ——— lepturus

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† There is nothing more worthy of obſervation than that admirable œconomy of Nature, by which the ſame animal accommodates itſelf to a change of climate or of manner of living, and adopts habits and propenſities ſuitable to its new ſituation. At the Cape of Good Hope the oſtrich inclines to ſit on her eggs like any other bird; but in Senegal, where the heat is great, ſhe leaves them to the ſun during the heat of the day. In thoſe countries where proviſions can be found during the greateſt part of the year, the bee gradually loſes the propenſity of laying up ſtores for the ſeaſon of winter; and in thoſe countries infeſted with monkies, many birds which in other climates build

in

Neele sculp. Strand.

But that which is moſt conſiderable in this matter, and plainly ſheweth the divine management in the caſe, is, that thoſe creatures are manifeſtly deſigned for the place in which they are, and the uſe and ſervices they perform therein ‡. If all the animals

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in buſhes and the clefts of trees, ſuſpend their neſts upon ſlender twigs, and by this ingenious device elude the rapacity of their enemies. But this accommodating power of animals is in nothing more truly wonderful, than in ſome facts relative to generation. It is a fact well known to naturaliſts, that certain animals are at one time oviparous, and at another viviparous. Mr. Bonnet has diſcovered that the *puceron* or vine-fretter, which generally propagates by an intercourſe of ſexes, is not only oviparous at one period, and viviparous at another, but in all caſes where the union of the ſexes is not to be obtained, can eaſily accompliſh all the purpoſes of generation without it.

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‡ Of this admirable œconomy the rein deer furniſhes a ſtrong example. This animal is peculiar to the northern regions of Lapland, Greenland, &c. and ſerves to ſupply moſt of the wants of the inhabitants of thoſe countries ſo little favoured by Nature. While its food is nothing elſe than a ſpecies of moſs which grows upon the rocks and barren mountains, its fleſh furniſhes a rich and wholeſome aliment, its milk a nutritive and delicious beverage, its ſkin a warm cloathing, and its bodily ſtrength and fleetneſs a ſpeedy and commodious conveyance for tranſporting its maſter over the trackleſs wilds of a country, which for three-fourths of the year preſents an unvaried ſurface of hardened ſnow. The rein deer will draw the ſledge for 30 or 40 miles at a ſtretch, without taſting food. In this ſervice he continues for 15 or 16 years; and when his ſtrength begins to fail, he is then ſlaughtered for proviſion to the family. His blood is preſerved in ſmall caſks, together with the marrow, and will

animals of our globe had been made by chance, or placed by chance, or without the Divine Providence, their organs would have been otherwife than they are, and their place and refidence confufed and jumbled. Their organs (for inftance) of refpiration, of vifion, and of motion, would have fitted any *medium*, or have needed none; their ftomachs would have ferved any food, and their blood, and covering of their bodies been made for any clime, or only one clime. Confequently all the animal world would have been in a confufed, inconvenient, and diforderly commixture. One animal would have wanted food, another habitation, and moft of them fafety. They would have all flocked to one, or a few places, taken up their reft in the temperate zones only, and coveted one food, the eafieft to be come at, and moft fpecious in fhew; and fo would have poifoned, ftarved, or greatly incommoded one another. But as the matter is now ordered, the globe is equally befpread, fo that no

will keep frefh for many months. His horns are converted into glue; his finews form a very ftrong thread for fewing the garment which is made of his fkin. The tongues, which are confidered as a great delicacy, are dried and fold into the more fouthern provinces. The milk of the females is made into butter and cheefe, of which the whey, by a mixture of wood forrel, becomes a kind of fermented liquor, of a flavour not unpleafant, and remarkably wholefome. Thus this fingle animal fupplies to the Laplander and Greenlander almoft all the wants and conveniencies, in fome refpects even the luxuries, of life.

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place

place wanteth proper inhabitants, nor any creature is deſtitute of a proper place, and all things neceſſary to its life, health, and pleaſure. As the ſurface of the terraqueous globe is covered with different ſoils, with hills and vales, with ſeas, rivers, lakes and ponds, with divers trees and plants, in the ſeveral places; ſo all theſe have their animal inhabitants, whoſe organs of life and action are manifeſtly adapted to ſuch and ſuch places and things; whoſe food and phyſic, and every other convenience of life, is to be met with in that very place appointed it. The watery, the amphibious (*a*), the airy inhabitants, and thoſe on the dry land ſurface, and the ſubterraneous under it, they all live and act with pleaſure, they are gay, and flouriſh in their proper element and allotted place, they want neither for food, cloathing, or retreat; which would dwindle and die, deſtroy, or poiſon one another, if all coveted the ſame element, place, or food.

(*a*) *Eſt etiam admiratio nonnulla in beſtiis aquatilibus iis, quæ gignuntur in terrâ: veluti crocodili, fluviatileſque teſtudines, quædamque ſerpentes ortæ extra aquam, ſimul ac primùm niti poſſunt, aquam perſequuntur. Quin etiàm anatum ova gallinis ſæpe ſupponimus*—[pulli] *deinde eas* [matres] *relinquunt—& effugiunt, cùm primùm aquam, quaſi naturalem domum, videre potuerunt.*—"It is likewiſe an admirable thing in ſome aquatic animals which are produced on land, ſuch as crocodiles, river-tortoiſes, and ſome ſerpents, that as ſoon as they are able to crawl, they betake themſelves to the water: ſo when ducks eggs are hatched by a hen, the chicks leave their mother, and as ſoon as they can ſee the water, run to it."—*Cic. de Nat. Deor.* l. 2. c. 48.

Nay, and as the matter is admirably well ordered, yet confidering the world's increafe, there would not be fufficient room, food, and other neceffaries for all the living creatures, without another grand act of the Divine wifdom and providence, which is the *balancing the number of individuals* of each fpecies of creatures, in that place appointed thereto: Of which in the next Chapter.

CHAP. X.

Of the Balance of Animals, or the due Proportion in which the World is ſtocked with them.

THE whole ſurface of our globe can afford room and ſupport only to ſuch a number of all ſorts of creatures. And if by their doubling, trebling, or any other multiplication of their kind, they ſhould increaſe to double or treble that number, they muſt ſtarve, or devour one another. The keeping therefore the balance even, is manifeſtly a work of the Divine wiſdom and providence. To which end, the great author of life hath determined the life of all creatures to ſuch a length, and their increaſe to ſuch a number, proportional to their uſe in the world. The life of ſome creatures is long, and their increaſe but ſmall, and by that means they do not over-ſtock the world. And the ſame benefit is effected, where the increaſe is great, by the brevity of ſuch creatures lives, by their great uſe, and the frequent occaſions there are of them for food to man or other animals. It is a very remarkable act of the Divine providence, that uſeful creatures are produced in great plenty (*a*), and

(*a*) *Benigna circa hoc Natura, innocua & eſculenta animalia fæcunda generavit.*—" Nature in her bounty hath rendered thoſe animals

and others in lefs. The prodigious and frequent increafe of infects *, both in and out of the waters, may exemplify the one; and it is obfervable in the other, that creatures lefs ufeful, or by their voracity pernicious, have commonly fewer young, or do feldomer bring forth: of which many inftances might be given in the voracious beafts and birds. But there is one fo peculiar an animal, as if made for a particular inftance in our prefent cafe, and that is the condor of *Peru* (*b*), a fowl of that magnitude,

animals very prolific, which are wholefome and fit for the food of man."—*Plin. Nat. Hift.* l. 8. c. 55.

(*b*) *Captain* J. Strong, *gave me this account, together with a quill-feather of the* condor *of* Peru. *On the coaft of* Chili, *they met with this bird in about* 33° *f. lat. not far from* Mocha, *an ifland in the fouth fea,—they fhot it fitting on a cliff, by the fea-fide; that it was* 16 *feet from wing to wing extended*; *that the* Spanifh *inhabitants told them they were afraid of thefe birds, left they fhould prey upon their children. And the feather he gave me* (faith the Doctor) *is two feet four inches long; the quill-part five inches three quarters*

* Linnæus was the firft who obferved one ufe of infects which his own hypothefis refpecting the generation of plants had led him to remark. This is, that by fhifting from one plant to another of the fame fpecies, they convey the pollen of the male plant to the ftigma of the female. "In this way," fays he, "it is reafonable to think that many dioicous plants are impregnated. Nay even the hermaphrodites themfelves are greatly obliged to the different tribes of infects, which by fluttering and treading in the corolla, are conftantly fcattering the pollen about the ftigma." EDITOR.

tude, ſtrength, and appetite, as to ſeize not only on the ſheep, and leſſer cattle, but even the larger beaſts, yea, the very children too. Now theſe, as they are the moſt pernicious of birds, ſo are they the moſt rare, being ſeldom ſeen, or only one, or a few in large countries; enough to keep up the ſpecies; but not to overcharge the world.

Thus the balance of the animal world, is, throughout all ages, kept even; and by a curious harmony and juſt proportion between the increaſe of all animals and the length of their lives, the world is through all ages well, but not over ſtored: *One generation paſſeth away, and another generation*

quarters long, and one inch and half about in the largeſt part. It weighed 3 *dr.* 17 *gr. and half, and is of a dark brown colour.* Dr. *Sloane* in Philoſ. Tranſ. No. 208.

To this account, the Doctor (in a letter to Mr. *Ray*, *March* 31, 1694, with other papers of Mr. *Ray*'s, in my hands) adds the teſtimony of *Joſ. Acoſta*, l. 4. c. 7. and *Garcilaſſ. de la Vega*, who, l. 8. c. 19. faith, *There are other fowls called by the* Spaniards Condor. *Many of theſe fowls, having been killed by the* Spaniards, *had their proportion taken, and from end to end of their wings meaſured* 15 *or* 16 *feet.—Nature, to temper and allay their fierceneſs, denied them the talons which are given to the* eagle; *their feet being tipped with claws like a hen: however, their beak is ſtrong enough to tear off the hide, and rip up the bowels of an* ox. *Two of them will attempt a* cow *or* bull, *and devour him: and it hath often happened, that one of them alone hath aſſaulted boys of ten or twelve years of age, and eaten them. Their colour is black and white, like a* magpie. *It is well there are but few of them; for if they were many, they would very much deſtroy the cattle. They have on the fore-part of their heads a comb, not pointed like that*

tion cometh (*c*); ſo equally in its room, to balance the ſtock of the terraqueous globe in all ages, and places, and among all creatures; that it is an actual demonſtration of our Saviour's aſſertion, *Mat.* x. 29. that the moſt inconſiderable, common creature, *even a ſparrow, (two of which are ſold for a farthing,) doth not fall on the ground without our heavenly Father.*

This providence of God is remarkable in every ſpecies of living creatures: but that eſpecial management of the recruits and decays of mankind, ſo equally all the world over, deſerves our eſpecial obſervation. In the beginning of the world, and ſo after *Noah*'s flood, the longevity of men, as it was of abſolute neceſſity to the more ſpeedy peopling of the new world; ſo is it a ſpecial inſtance of the Divine Providence in this matter (*d*). And the ſame

that of a cock; but rather even, in the form of a razor. When they come to alight from the air, they make ſuch a humming noiſe, with the fluttering of their wings, as is enough to aſtoniſh, or make a man deaf.

(*c*) *Eccleſ.* i. 4.

(*d*) The divine providence doth not only appear in the longevity of man, immediately after the creation and flood; but alſo in their different longevity at thoſe two times. Immediately after the creation, when the world was to be peopled by one man, and one woman, the age of the greateſt part of thoſe on record, was 900 years, and upwards. But after the flood, when there were three perſons by whom the world was to be peopled, none of thoſe patriarchs, except *Shem*, arrived to the age of 500; and only the three firſt of *Shem*'s line, viz. *Arphaxad*, *Salah*, and *Eber*,

ſame Providence appears in the following ages, when the world was pretty well peopled, in reducing the common age of man then to 120 years, (*Gen.* vi. 3.) in proportion to the occaſions of the world at that time. And laſtly, when the world was fully peopled after the flood, (as it was in the age of *Moſes*, and ſo down to our preſent time,) the leſſening the common age of man to 70 or 80 years (*e*), (the age mentioned by *Moſes*, *Pſal.* xc. 10. this

Eber, came near that age; which was in the firſt century after the flood. But in the ſecond century, we do not find any reached the age of 240. And in the third century, (about the latter end of which *Abraham* was born,) none, except *Terah*, arrived to 200 years: by which time the world was ſo well peopled, (that part of it, at leaſt, where *Abraham* dwelt,) that they had built cities, and began to be cantoned into diſtinct nations and ſocieties, under their reſpective kings; ſo that they were able to wage war, four kings againſt five. *Gen.* xiv. Nay, if the accounts of *Anian*, *Berothus*, *Manetho*, and others, yea *Africanus*, be to be credited; the world was ſo well peopled, even before the times we ſpeak of, as to afford ſufficient numbers for the great kingdoms of *Aſſyria*, *Egypt*, *Perſia*, &c. But learned men generally, with great reaſon, reject theſe as legendary accounts.

If the reader hath a mind to ſee a computation of the increaſe of mankind, in the three firſt centuries after the flood, he may find two different ones of the moſt learned archbiſhop *Uſher*, and *Petavius*; together with a refutation of the ſo early beginning of the *Aſſyrian monarchy*; as alſo reaſons for placing *Abraham* near 1000 years after the flood, in our moſt learned biſhop *Stillingfleet's Orig. Sacr. Book* iii. *chap.* 4. *ſect.* 9.

(*e*) That the common age of man hath been the ſame in all ages ſince the world was peopled, is manifeſt from profane as well

this, I ſay,) is manifeſtly an appointment of the ſame infinite Lord that ruleth the world: for, by this

well as ſacred hiſtory. To paſs by others: *Plato* lived to the age of 81, and was accounted an old man. And thoſe which *Pliny* reckons up, *l.* 7. *c.* 48., as rare examples of long life, may for the moſt part be matched by our modern hiſtories; eſpecially ſuch as *Pliny* himſelf gave credit unto. Dr. *Plot* hath given us divers inſtances in his hiſtory of *Oxfordſhire*, c. 2. ſect. 3. and *c.* 8. ſect. 54. and Hiſtory of *Staffordſhire*, c. 8. ſect. 91, &c. Among others, one is of twelve tenants of Mr. *Biddulph*'s, that together made 1000 years of age. But the moſt conſiderable examples of aged perſons among us, is of old *Parr* of *Shropſhire*, who lived 152 years nine months, according to the learned Dr. *Harvey*'s account; and *Henry Jenkins* of *Yorkſhire*, who lived 169 years, according to the account of my learned and ingenious friend Dr. *Tancred Robinſon*; of both which, with others, ſee *Lowth. Abridg. Phil. Tranſ.* v. iii. p. 306. The great age of *Parr* of *Shropſhire* minds me of an obſervation of the reverend Mr. *Plaxton*, that in his two pariſhes of *Kinardſey* and *Donington* in *Shropſhire*, every ſixth ſoul was 60 years of age, or upwards. *Phil. Tranſ.* No. 310.

And if we ſtep farther north into *Scotland*, we ſhall find divers recorded for their great age: of which I ſhall preſent the reader with only one modern example of one *Laurence*, who married a wife after he was 100 years of age, and would go out to ſea a fiſhing in his little boat, when he was 140 years old; and is lately dead of no other diſtemper but mere old age, faith Sir *Rob. Sibbald*, *Prodr. Hiſt. Nat. Scot.* p. 44. and l. 3. p. 4.

As for foreigners, the examples would be endleſs; and therefore that of *Joh. Ottele* ſhall ſuffice, who was as famous for his beard, as for being 115 years of age. He was but two *Brabant* ells $\frac{3}{9}$ high; and his long grey beard was one ell $\frac{1}{4}$ long. His picture and account may be ſeen in *Ephem. Germ. T.* 3. *Obſ.* 163.

As for the ſtory *Roger Bacon* tells, of one that lived 900 years by the help of a certain medicine, and many other ſuch ſtories,

this means, the peopled world is kept at a convenient ſtay; neither too full, nor too empty. For if men (the generality of them, I mean) were to live now to *Methuſelah*'s age of 969 years, or only to *Abraham*'s, long after the flood, of 175 years, the world would be too much over-run; or if the age of man was limited to that of divers other animals, to ten, twenty, or thirty years only; the decays then of mankind would be too faſt: but at the middle rate mentioned, the balance is nearly even, and life and death keep an equal pace. Which equality is ſo great and harmonious, and ſo manifeſt an inſtance of the divine management, that I ſhall ſpend ſome remarks upon it.

ſtories, I look upon them as fabulous. And no better is that of the *wandering Jew*, named *Joh. Buttadæus*, ſaid to have been preſent at our Saviour's crucifixion: although very ſerious ſtories are told of his being ſeen at *Antwerp*, and in *France*, about the middle of the laſt century but one; and before in *ann.* 1542, converſed with by *Paul* of *Eitſen*, biſhop of *Sleſwick*; and before that, *viz.* in 1228, ſeen and converſed with by an *Armenian archbiſhop's gentleman*; and by others at other times.

If the reader hath a mind to ſee more examples, he may meet with ſome of all ages, in the learned *Hakewill's Apol.* p. 181. where he will alſo find that learned author's opinion of the cauſes of the brevity and length of human life. The brevity thereof he attributeth to a too tender education, ſucking ſtrange nurſes, too haſty marriages; but above all, to luxury, high ſauces, ſtrong liquors, &c. The longevity of the antients he aſcribes to temperance in meat and drink, anointing the body, the uſe of ſaffron and honey, warm clothes, leſſer doors and windows, leſs phyſic and more exerciſe.

It appears from our beſt accounts of theſe matters, that in our *European* parts (*f*), and I believe the ſame is throughout the world; that, I ſay, there is a certain rate and proportion in the propagation

(*f*) The proportions which *marriages* bear to *births*, and *births* to *burials*, in divers parts of *Europe*, may be ſeen at an eaſy view in this TABLE:

NAMES OF THE PLACES.	Marriages to Births: as	Births to Burials: as
England in general.	1 to 4'63	1'12 to 1
London.	1 to 4'	1 to 1'1
Hantſhire, from 1569, to 1658.	1 to 4'	1'2 to 1
Tiverton in *Devon*. 1560, to 1649.	1 to 3'7	1'26 to 1
Cranbrook in *Kent*, 1560, to 1649.	1 to 3'9	1'6 to 1
Ayhno in *Northamptonſh.* for 118 years.	1 to 6	1'6 to 1
Leeds in *Yorkſhire* for 122 years.	1 to 3'7	1'07 to 1
Harwood in *Yorkſhire* 57 years.	1 to 3'4	1'23 to 1
Upminſter in *Eſſex* 100 years.	1 to 4'6	1'08 to 1
Frankfort on the *Main* in 1695.	1 to 3'7	1'2 to 1
Old middle and lower *Marck* in 1698.	1 to 3'7	1'9 to 1
Domin. of the K. of *Pruſſia* in 1698.	1 to 3'7	1'5 to 1
Breſlaw in *Sileſia* from 1687, to 1691.		1'6 to 1
Paris in 1670, 1671, 1672.	1 to 4'7	1' to 1'6

Which table I made from major *Graunt*'s obſervations on the bills of mortality; Mr. *King*'s obſervations in the firſt of Dr. *Davenant*'s eſſays; and what I find put together by my ingenious friend Mr. *Lowthorp*, in his Abridgment, vol. 3. p. 668, and my own regiſter of *Upminſter*. That from *Aynho* regiſter in *Northamptonſhire*, I had from the preſent rector, the learned and ingenious Mr. *Waſſe*: and I was promiſed ſome accounts from the north, and divers other parts of this kingdom; but have not yet received them: only thoſe of *Leeds* and *Harwood* in *Yorkſhire*, from my curious and ingenious friend Mr. *Thoreſby*.

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of mankind: ſuch a number marry (*g*), ſo many are born, ſuch a number die; in proportion to the number of perſons in every nation, county, or pariſh. And as to births, two things are very conſiderable: one is the proportion of males and females (*h*), not in a wide proportion, not an uncertain,

(*g*) The preceding table ſhevs, that marriages, one with another, do each of them produce about four births; not only in *England*, but in other parts of *Europe* alſo.

And by Mr. *King*'s eſtimate, (the beſt computations I imagine of any, being derived from the beſt accounts; ſuch as the marriage, birth, burial-act, the poll-books, &c. by his eſtimate, I ſay,) about one in 104 marry. For he judgeth the number of the people in *England*, to be about five millions and a half; of which about 41,000 annually marry. As to what might be farther remarked concerning marriages, in regard of the rights and cuſtoms of ſeveral nations, the age to which divers nations limited marriages, &c. it would be endleſs, and too much out of the way to mention them: I ſhall only therefore, for the reader's diverſion, take notice of the jeer of *Lactantius*, *quare apud poetas ſalaciſſimus* Jupiter *deſiit liberos tollere? Utrum ſexagenarius factus, & ei lex Papia fibulam impoſuit?*—"Why has Jupiter, the moſt ſalacious of all the gods, ceaſed to have progeny? Is it that, being now above ſixty years old, he is padlocked by the Papian law."—Lactant. Inſtit. l. 1. c. 16. By which *lex Papia*, men were prohibited to marry after 60, and women after 50 years of age.

(*h*) Major *Graunt* (whoſe concluſions ſeem to be well-grounded) and Mr. *King* diſagree in the proportions they aſſign to males and females. This latter makes in *London* 10 males to be to 13 females; in other cities and market-towns, 8 to 9; and in the villages and hamlets, 100 males to 99 females. But major *Graunt*, both from the *London* and country bills, ſaith, there are 14 males to 13 females: from whence he juſtly infers, *That the Chriſtian religion, prohibiting polygamy, is more agreeable to the law of Nature than* Mahometiſm, *and others that allow it*, c. 8.

tain, accidental number at all adventures; but nearly equal. Another thing is, that a few more are born than appear to die, in any certain place(*i*); which

This proportion of 14 to 13, I imagine, is nearly juſt, it being agreeable to the bills I have met with, as well as thoſe in Mr. *Graunt*. In the 100 years, for example, of my own pariſh-regiſter, although the burials of males and females were nearly equal, being 636 males, and 523 females, in all that time; yet there were baptiſed 709 males, and but 675 females, which is 13 females to 13'7 males. Which inequality ſhews, not only, that one man ought to have but one wife; but alſo that every woman may, without polygamy, have an huſband, if ſhe doth not bar herſelf by the want of virtue, by denial, *&c.* Alſo this ſurpluſage of males is very uſeful for the ſupplies of war, the ſeas, and other ſuch expences of the men above the women.

That this is a work of the Divine Providence, and not a matter of chance, is well made out by the very laws of chance, by a perſon able to do it, the ingenious and learned Dr. *Arbuthnot*. He ſuppoſeth *Thomas* to lay againſt *John*, that for 82 years running, more males ſhall be born than females; and giving all allowances in the computation to *Thomas*'s ſide, he makes the odds againſt *Thomas*, that it doth not happen ſo, to be near five millions of millions, of millions, of millions to one; but for ages of ages (according to the world's age) to be near an infinite number to one againſt *Thomas*. Vide *Phil. Tranſ.* No. 328.

(*i*) The foregoing table ſhews, that in *England* in general, fewer die than are born, there being but one death to 1 $\frac{12}{100}$ births. But in *London* more die than are born. So by Dr. *Davenant*'s table, the cities likewiſe and market-towns bury 1 $\frac{7}{100}$ to one birth. But in *Paris* they out-do *London*, their deaths being 1 $\frac{1}{2}$ to one birth: the reaſon of which I conceive is, becauſe their houſes are more crowded than in *London*. But in the villages of *England*, there are fewer die than are born, there being but 1 death to 1 $\frac{1}{10}$ births. And yet major *Graunt*, and Dr. *Davenant* both obſerve, there are more breeders in *London*, and the cities

which is an admirable provifion for the extraordinary emergencies and occafions of the world; to fupply unhealthful places, where death out-runs life; to make up the ravages of great plagues and difeafes, and the depredations of war and the feas; and to afford a fufficient number for colonies in the unpeopled parts of the earth. Or on the other hand, we may fay, that fometimes thofe extraordinary expences of mankind may be not only a juft punifhment of the fins of men; but alfo a wife means to keep the balance of mankind even; as one would be ready to conclude, by confidering the *Afiatic* and other the more fertile countries, where prodigious multitudes are yearly fwept away with great plagues, and fometimes war; and yet thofe countries are fo far from being wafted, that they remain full of people.

And now upon the whole matter, What is all this but admirable and plain management? What can the maintaining, throughout all ages and places, thefe proportions of mankind, and all other creatures; this harmony in the generations of men be, but the work of One that ruleth the world?

cities and market-towns, than are in the country, notwithftanding the *London* births are fewer than the country; the reafon of which fee in *Graunt*, c. 7. and *Davenant*, *ubi fupra*, p. 21.

The laft remark I fhall make from the foregoing table fhall be, that we may from thence judge of the healthfulnefs of the places there mentioned. If the year 1698 was the mean account of the three *Marcks*, thofe places bid the faireft for being moft healthful; and next to them *Aynho* and *Cranbrook* for *Englifh* towns.

Is it poſſible that every ſpecies of animals ſhould ſo evenly be preſerved, proportionate to the occaſions of the world? That they ſhould be ſo well balanced in all ages and places, without the help of Almighty wiſdom and power? How is it poſſible by the bare rules and blind acts of Nature, that there ſhould be any tolerable proportion; for inſtance, between males and females, either of mankind, or of any other creature (*k*); eſpecially ſuch as are of a ferine, not of a domeſtic nature, and conſequently out of the command and management of man? How could life and death keep ſuch an even pace through all the animal world? If we ſhould take it for granted, that, according to the ſcripture hiſtory, the world had a beginning, (as who can deny it (*l*)? or if we ſhould ſuppoſe the deſtruction

(*k*) *Quid loquar, quanta ratio in beſtiis ad perpetuam conſervationem earum generis appareat? Nam primùm aliæ mares, aliæ fæminæ ſunt, quod perpetuitatis causâ machinata Natura eſt.*—"What is more admirable than the proportion obſerved by Nature between the numbers of males and females in the different tribes of animals, ſo wiſely ordered for the preſervation of the ſpecies?"—*Cic. de Nat. Deor.* l. 2. c. 51.

(*l*) Although *Ariſtotle* held the eternity of the world, yet he ſeems to have retracted that opinion, or to have had a different opinion when he wrote his *Metaphyſics*; for in his firſt book he affirms, that *God is the cauſe and beginning of all things*; and in his book *de Mundo* he ſaith, *There is no doubt but God is the maker and conſervator of all things in the world.* And the *Stoic*'s opinion is well known, who ſtrenuouſly contended, That the contrivance and beauty of the heavens and earth, and all creatures, was owing to a wiſe, intelligent Agent. Of which *Tully* gives a large account in his ſecond book *de Nat. Deor.* in the perſon of *Balbus*.

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thereof by *Noah*'s flood: how is it poſſible, after the world was repleniſhed,) that in a certain number of years, by the greater increaſes and doublings of each ſpecies of animals; that, I ſay, this rate of *doubling* (m) ſhould ceaſe; or that it ſhould be compenſated

(m) I have before, in *note* (g), obſerved, That the ordinary rate of the doubling or increaſe of mankind is, that every marriage, one with another, produces about four births; but ſome have much exceeded that. *Babo*, earl of *Abenſperg*, had 32 ſons and eight daughters; and being invited to hunt with the emperor *Henry* II. and bring but few ſervants, brought only one ſervant, and his 32 ſons. To theſe many others might be added; but one of the moſt remarkable inſtances I have any where met with, is that of Mrs. *Honywood*, mentioned by *Hakewill*, *Camden*, and other authors; but having now before me the names, with ſome remarks, (which I received from a pious neighbouring deſcendant of the ſame Mrs. *Honywood*,) I ſhall give a more particular account than they. Mrs. *Mary Honywood* was daughter and one of the co-heireſſes of *Robert Atwaters*, Eſq. of *Lenham* in *Kent*. She was born in 1527, married in *February* 1543, at 16 years of age, to her only huſband *Robert Honywood*, of *Charing* in *Kent*, Eſq. She died in the 93d year of her age, in *May* 1620. She had 16 children of her own body, ſeven ſons and nine daughters: of which one had no iſſue, three died young, and the youngeſt was ſlain at *Newport*-battle, *June* 20, 1600. Her grand-children in the ſecond generation, were 114; in the third, 228; and nine in the fourth generation. So that ſhe could ſay the ſame that the diſtich doth, made of one of the *Dalburg*'s family of *Baſil*:

Mater ait Natæ (1), *dic Natæ* (2), *filia* (3) *Natam* (4)
Ut moneat, Natæ (5), *plangere Filiolam* (6).

Riſe up Daughter (1), *and go to thy Daughter* (2), *for her Daughter's* (3) *Daughter* (4) *hath a Daughter* (5)(6). Mrs. *Honywood* was a very pious woman,

penſated by ſome other means? That the world ſhould be as well, or better ſtocked than now it is, in 1656 years, (the time between the creation and the flood; this,) we will ſuppoſe may be done by the natural methods of each ſpecies doubling or increaſe: but in double that number of years, or at this diſtance from the flood, of 4000 years, that the world ſhould not be over-ſtocked, can never be made out, without allowing an infinite Providence.

I conclude then this obſervation with the Pſalmiſt's words, *Pſal.* civ. 29, 30, *Thou hideſt thy face, all creatures are troubled; thou takeſt away their breath, they die, and return to their duſt. Thou ſendeſt forth thy Spirit, they are created; and thou reneweſt the face of the earth.*

woman, afflicted, in her declining age, with deſpair, in ſome meaſure; concerning which, ſome divines once diſcourſing with her, ſhe in a paſſion ſaid, *She was as certainly damned as this glaſs is broken* (throwing a *Venice* glaſs againſt the ground, which ſhe had then in her hand). But the glaſs eſcaped breaking, as credible witneſſes atteſted.

END OF THE FIRST VOLUME.